Introduction to Digestion

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2015

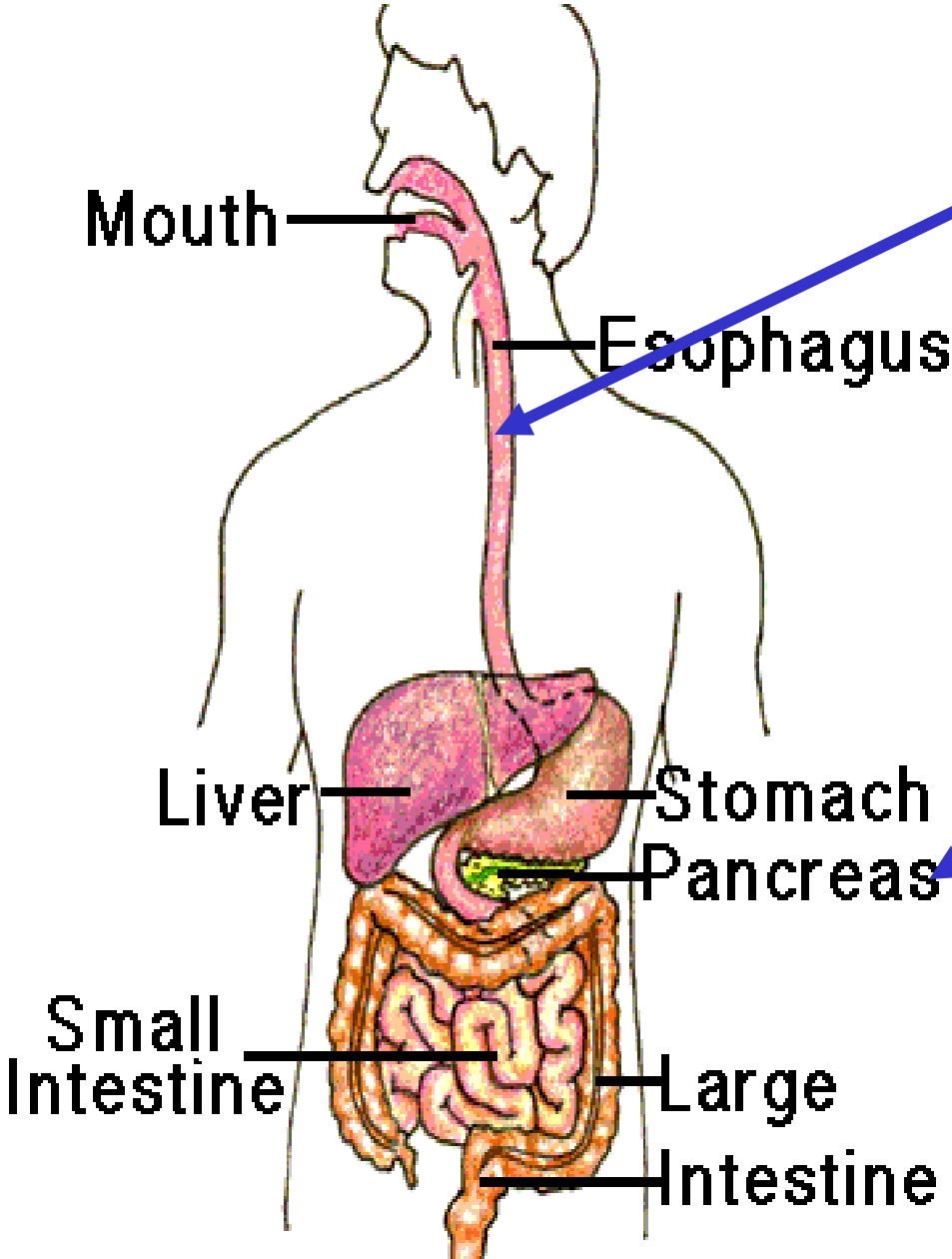
qums

Digestive System is composed of:

1-Digestive tract

AND

2- Accessory Organs

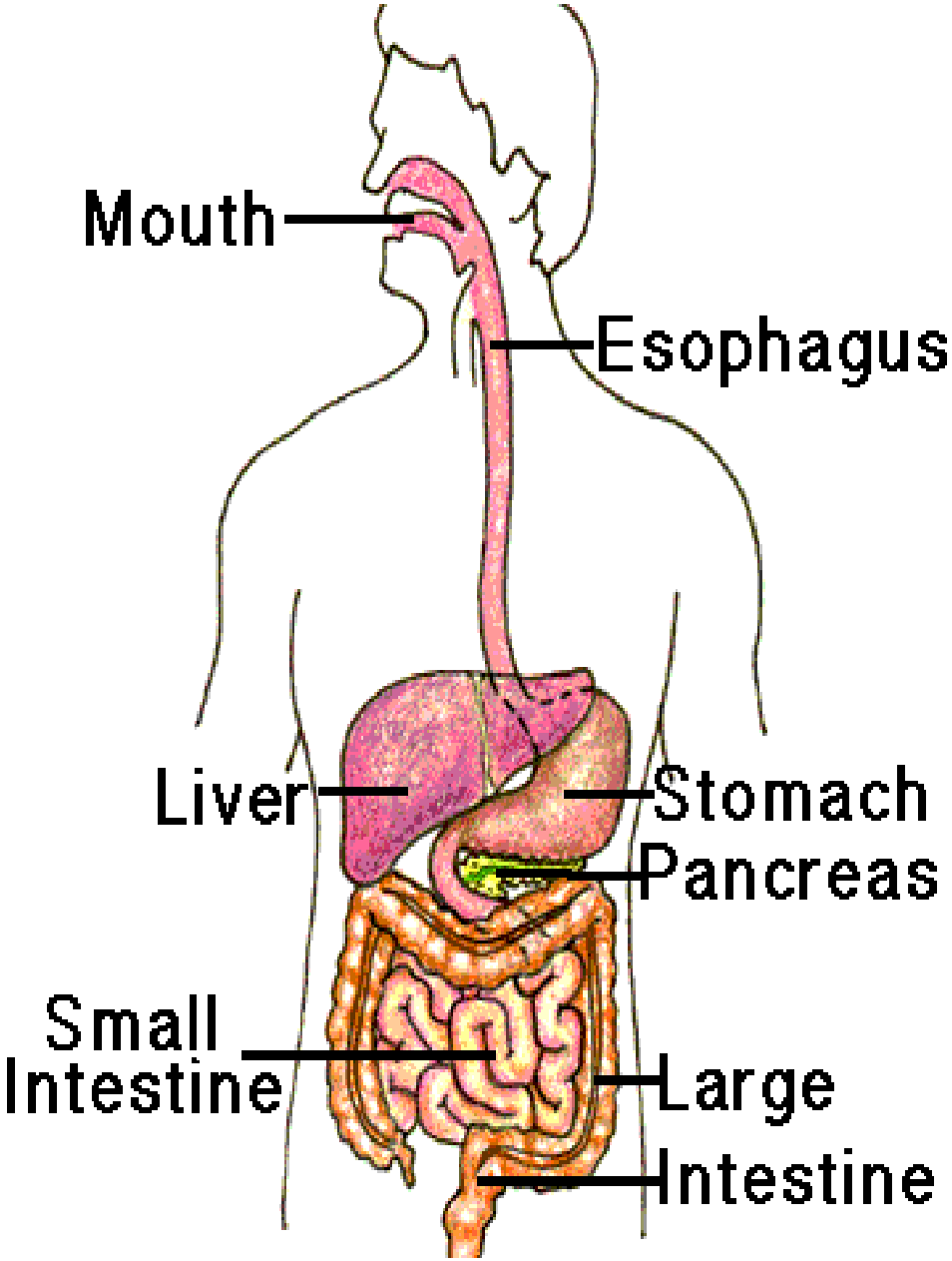


Digestive System

The primary function of the gastrointestinal (alimentary) tract is:

to process ingested food and provide the body with

- nutrients
- water
- electrolytes



Function of the Digestive System

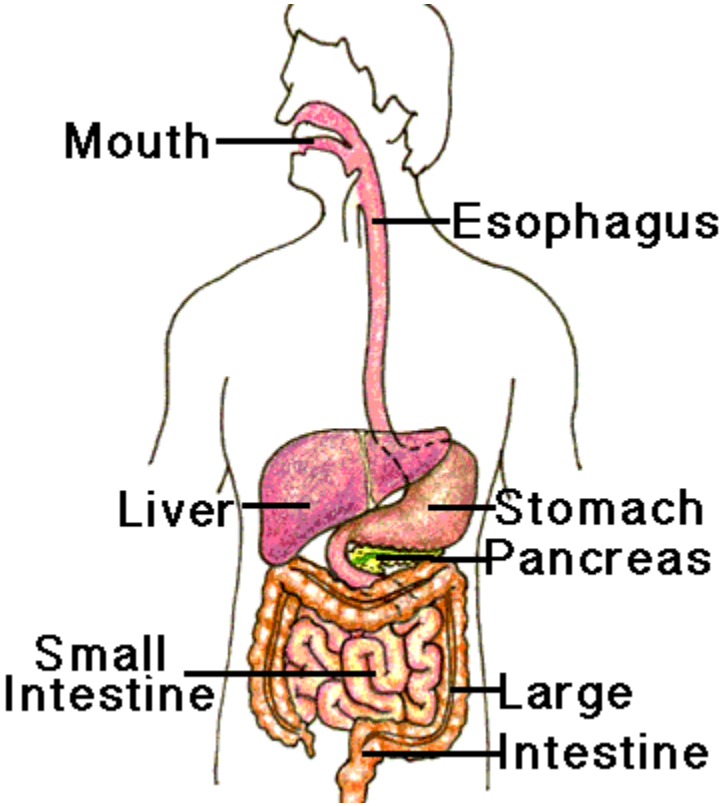
(A) motility

(B) Secretion and Digestion

Dissolving and breaking-down of nutrients into smaller units

(c) Absorption

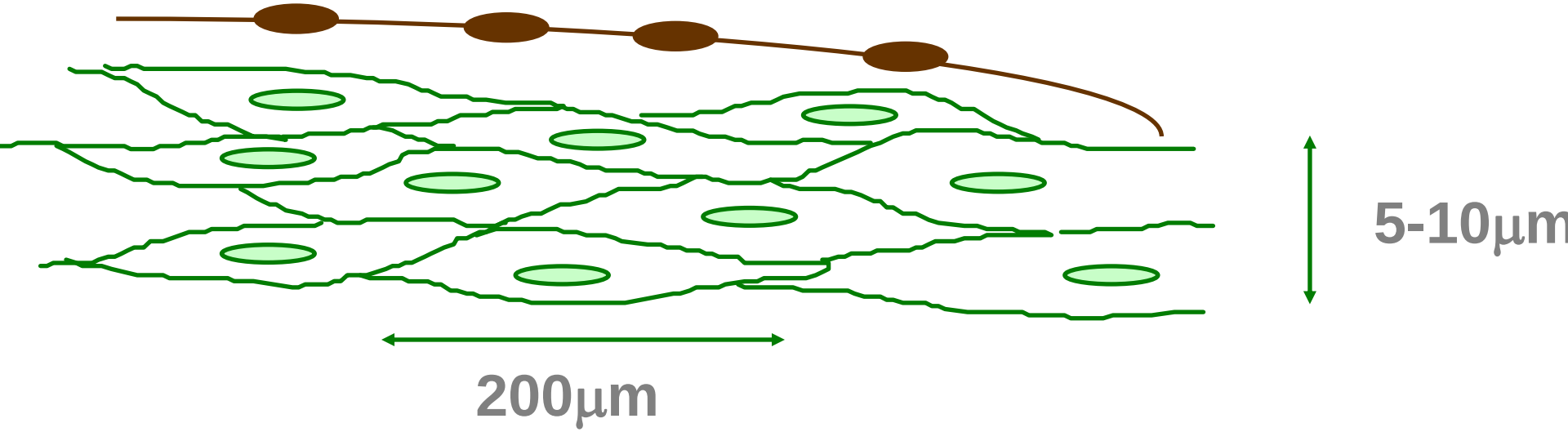
Absorption of these units (+ water) through the intestinal tract into the blood or lymph system



Epithelium
Villus
Lamina propria
Serosa
Muscularis Mucosae
Gland in submucosa
Submucosa
Longitudinal
Circular
Lymph node

Smooth Muscle

Properties of GI smooth muscle

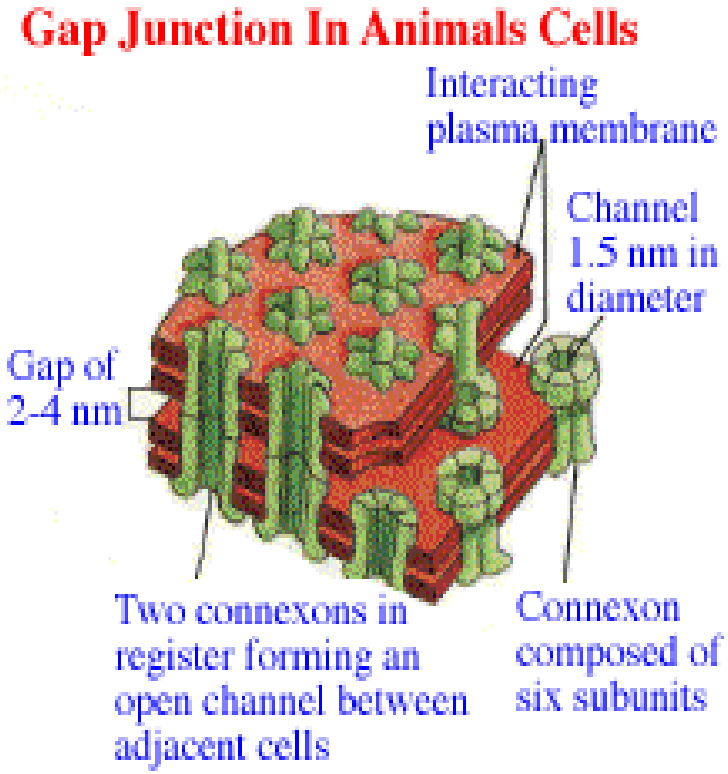


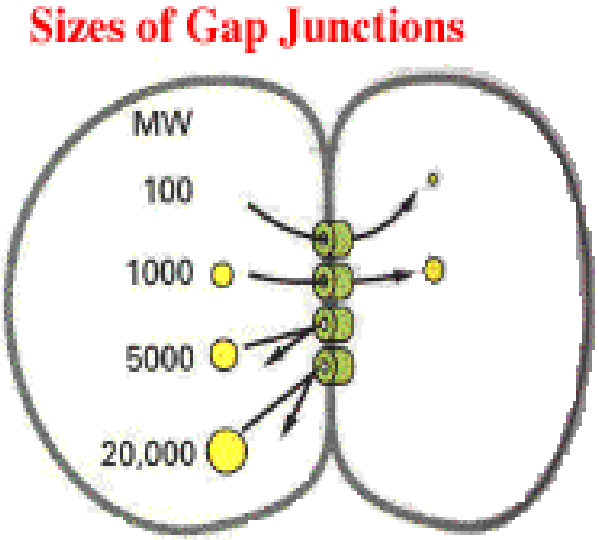
Form hollow tubes ∴
Form a syncitium - electrically coupled, joined by gap junctions ∴ contractions synchronous
Actin:myosin ratio 15:1 (skeletal muscle 2:1)
Contractile elements not arranged in sarcomeres ∴ not striated
Stimulated by neurotransmitter released from varicosities
Have slow wave activity

Gap junctions

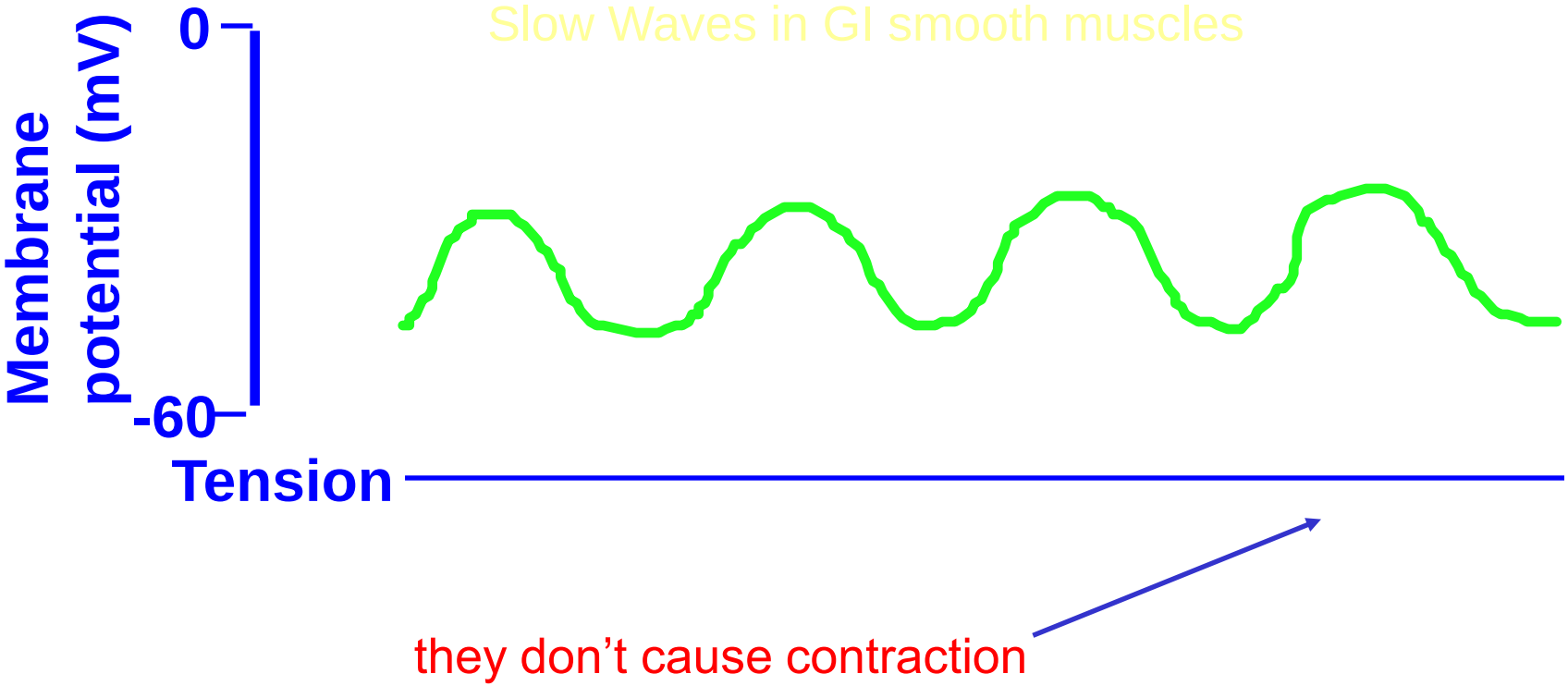
Syncitium - electrically coupled, joined by gap junctions ∴

Helps synchronous contractions





Electrical Activity



They are present in GI smooth muscle except in esophgagus and proximal part of Stomach

They oscillate between -50 to -65 mV

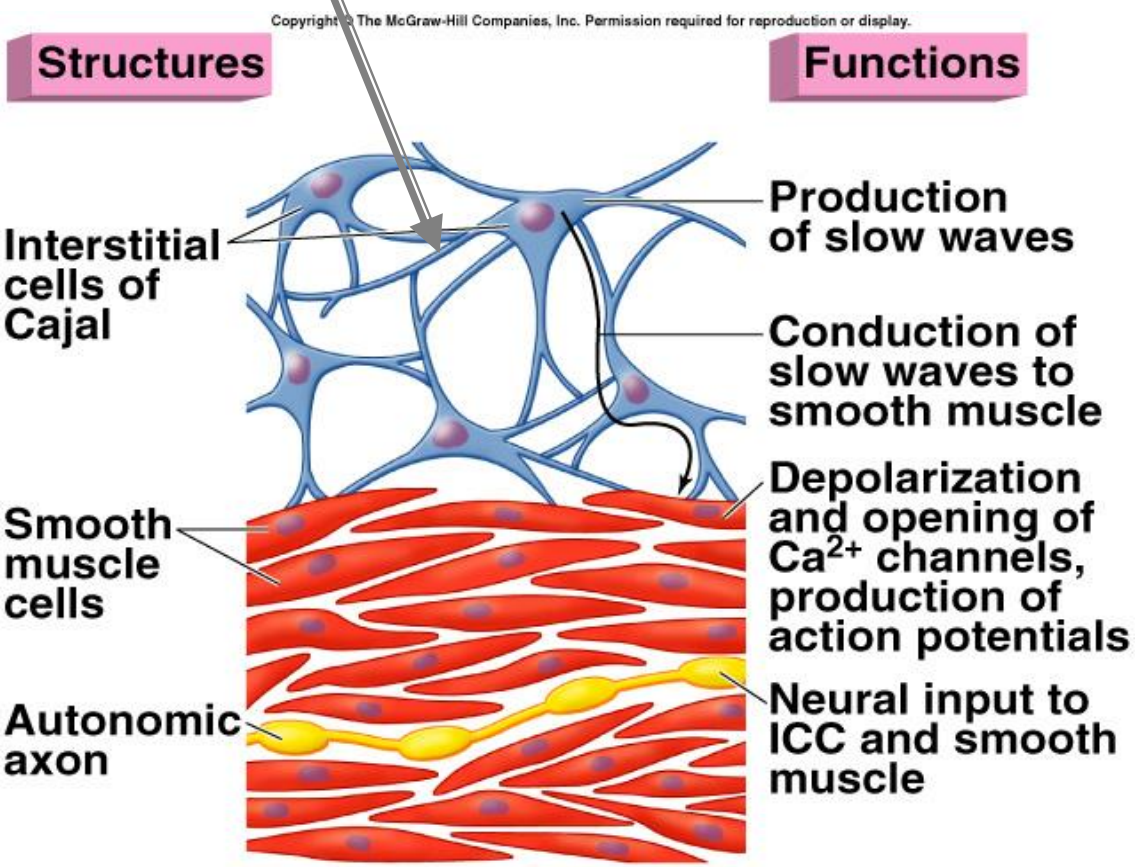
Oscillation of ?

Slow waves are produced by interstitial cells of Cajal

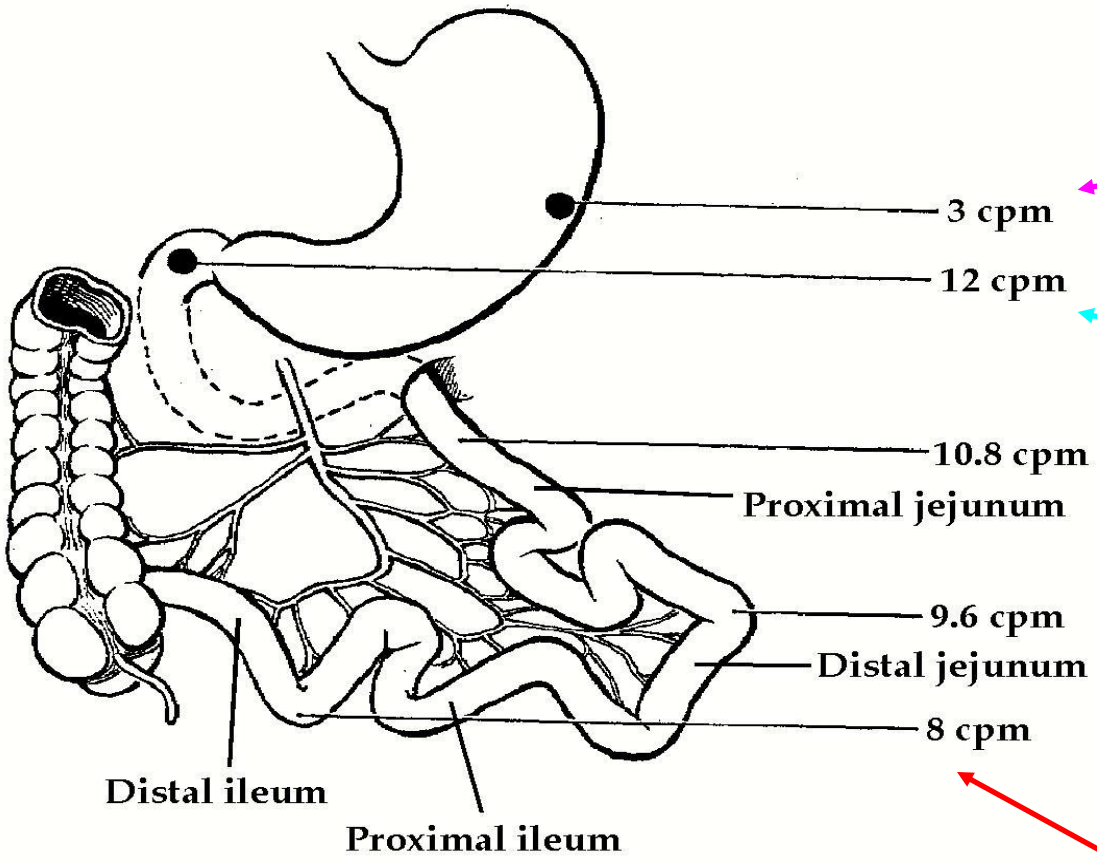
They are located in a thin layer between the longitudinal and circular layers of muscularis externa

They have properties of both fibroblast and smooth muscle

They have junctions with both circular and longitudinal smooth muscle



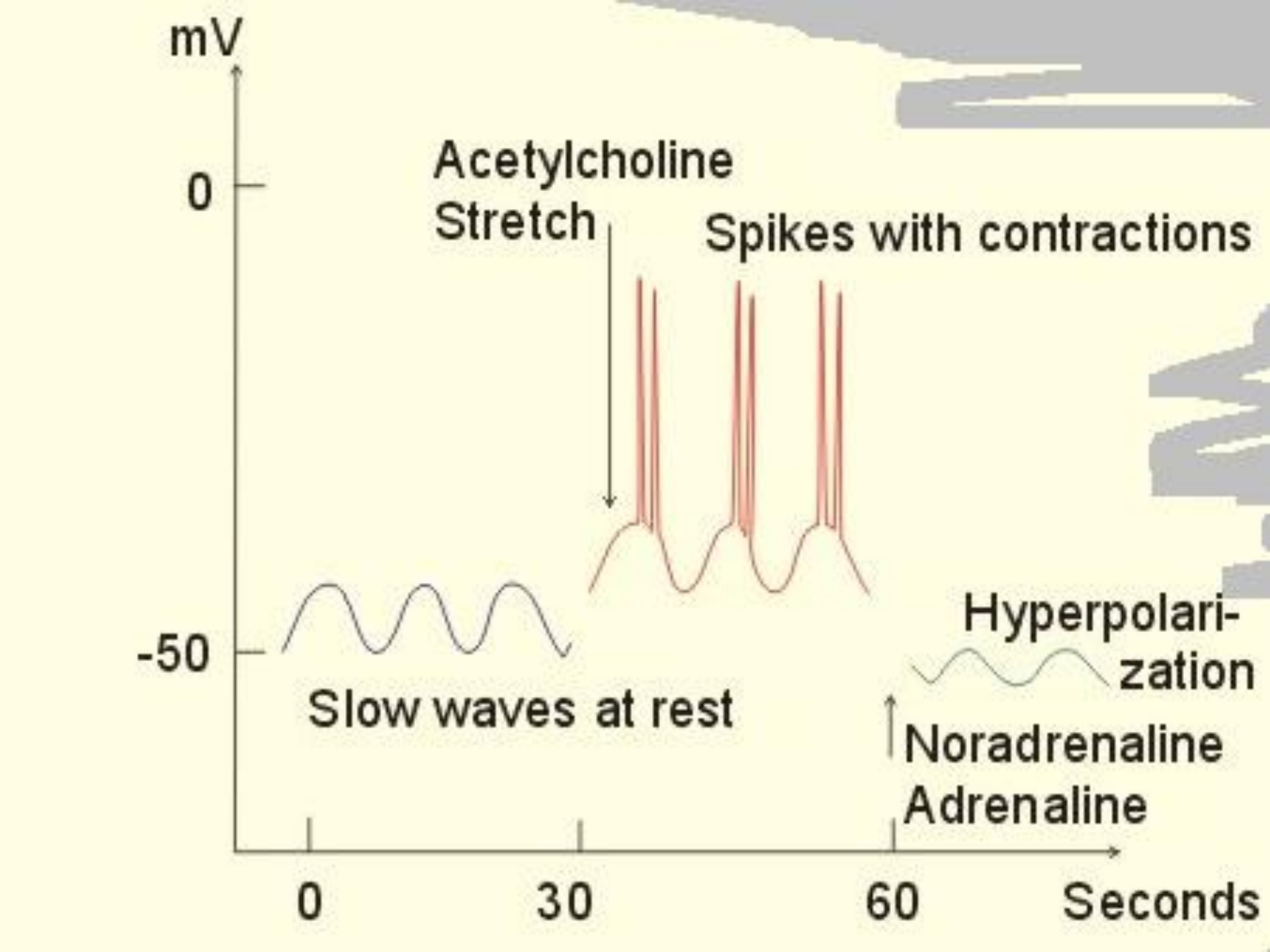
Slow Wavenumber in each part



In Stomach it is

In Duodenum it is

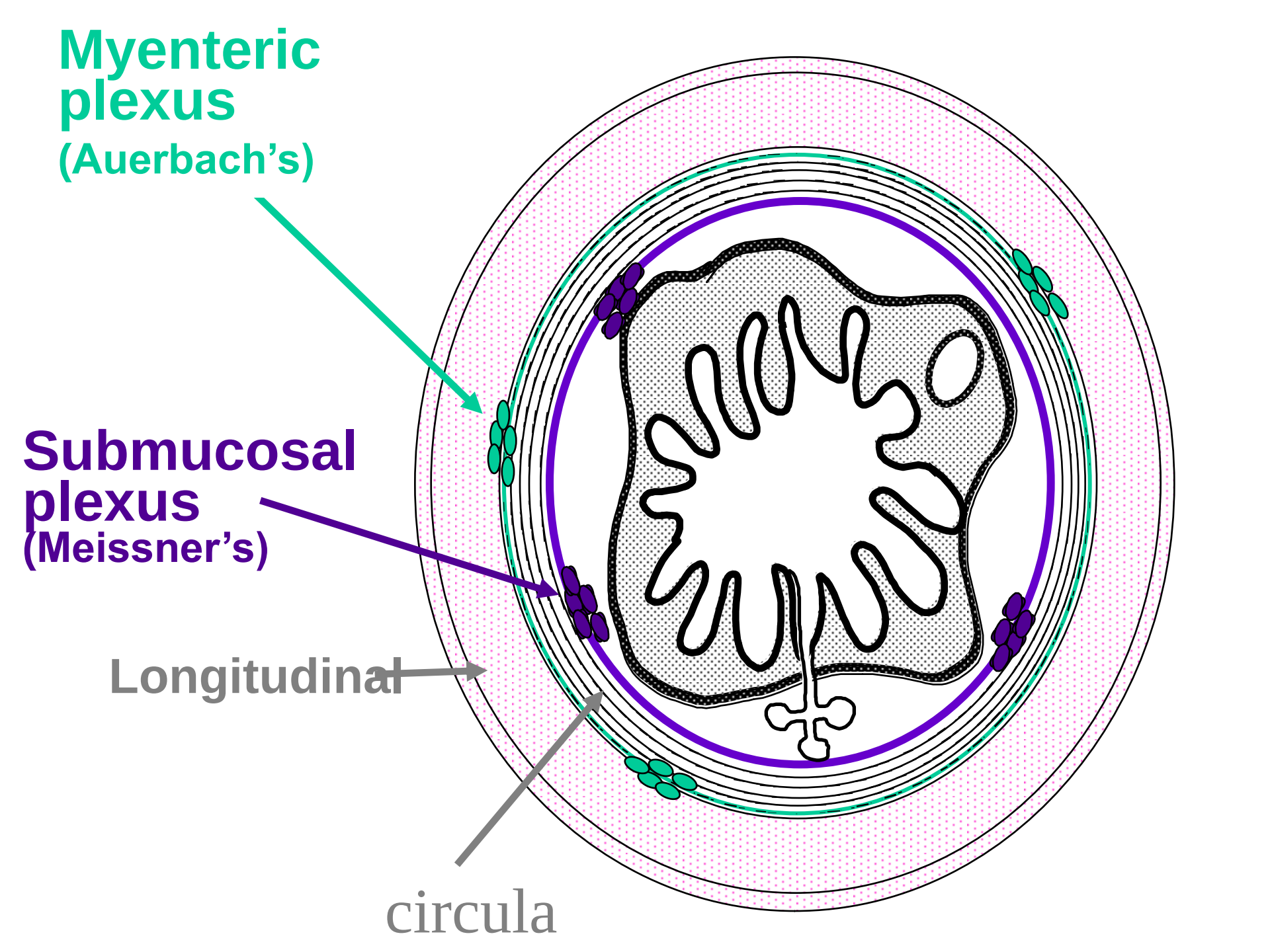
In terminal ileum it is

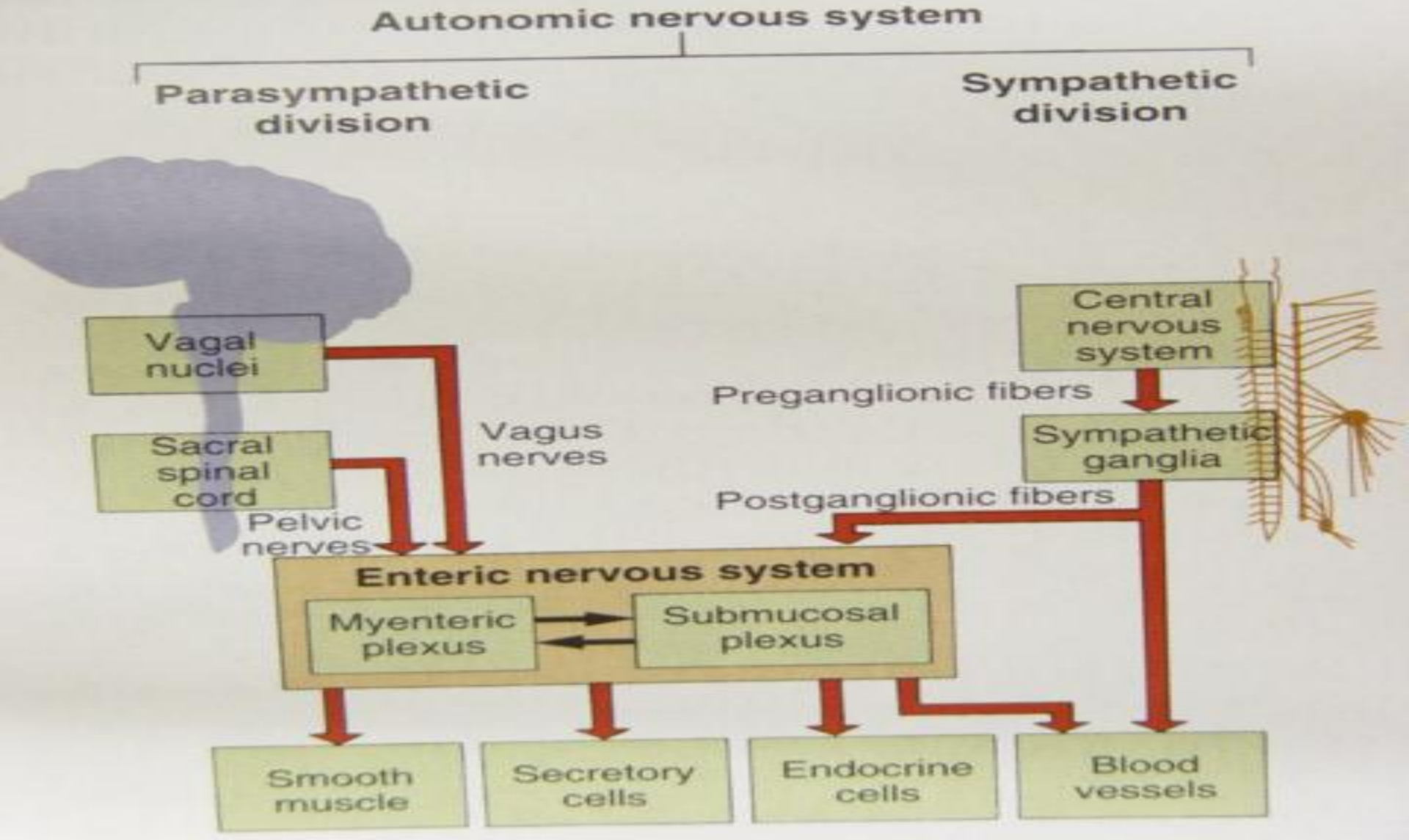

mV
0
-50
Acetylcholine
Stretch
Spikes with contractions
Hyperpolari-
zation
Slow waves at rest
Noradrenaline
Adrenaline
0
30
60
Seconds

GI Innervation

- Intrinsic (Entric Nervous System)
- Extrinsic (Autonum)

Entric Nervous System


Myenteric plexus
(Auerbach's)
Submucosal plexus
(Meissner's)
Longitudinal
circula


Autonomic nervous system
Parasympathetic division
Sympathetic division
Vagal nuclei
Sacral spinal cord
Vagus nerves
Pelvic nerves
Central nervous system
Preganglionic fibers
Sympathetic ganglia
Postganglionic fibers
Enteric nervous system
Myenteric plexus
Submucosal plexus
Smooth muscle
Secretory cells
Endocrine cells
Blood vessels

Functions of extrinsic nervous system

- Parasympathetic stimulation:

  A general increase in activity of the entire enteric nervous system

- Sympathetic stimulation:

  Generally inhibits GI system activity

  (There are some exceptions: in muscularis mucosa, sphincter, and GI vessels it stimulates smooth muscle contraction)

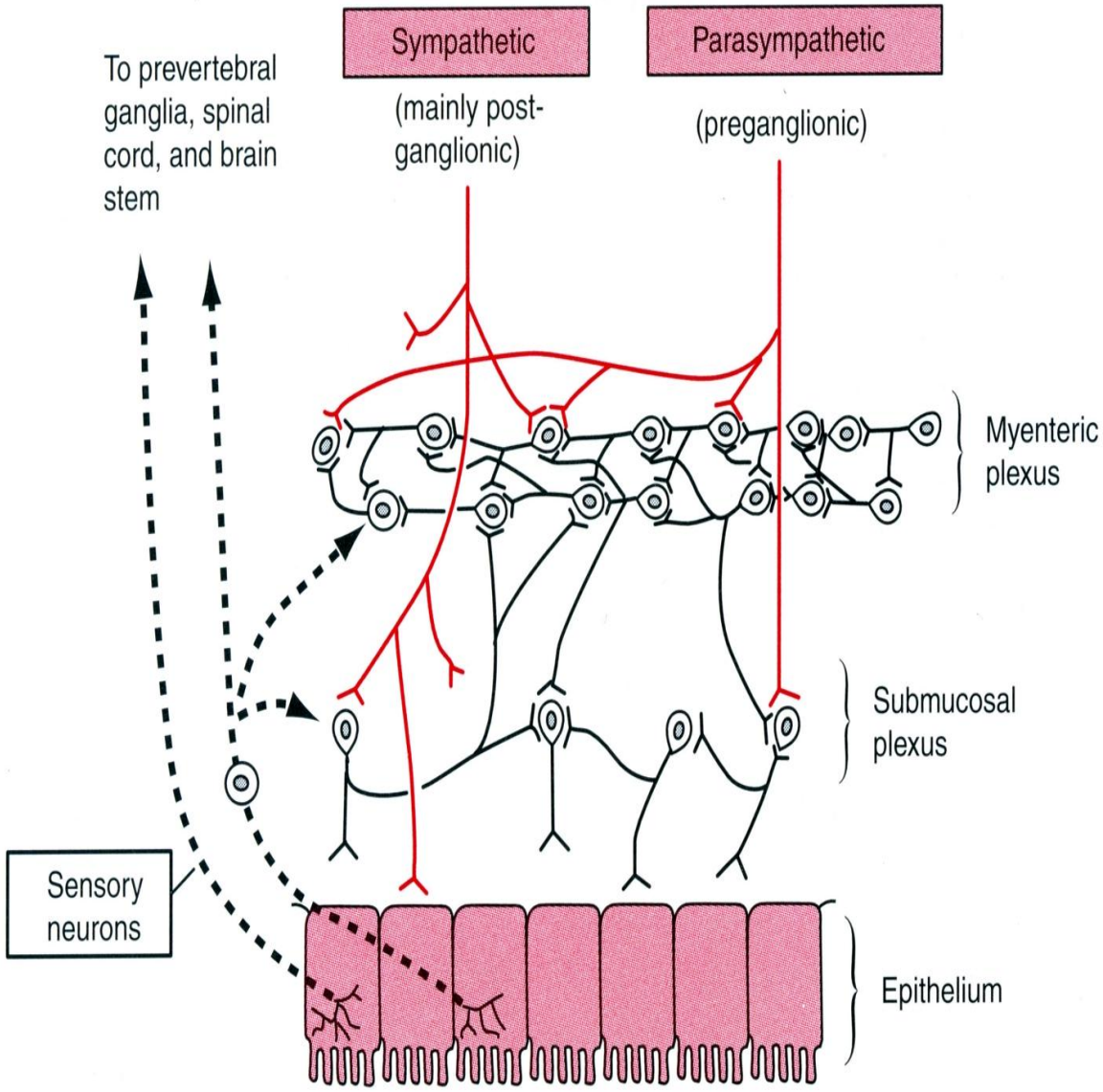
Afferent Nerves from Gut

- There are sensory nerves in epithelium or gut wall
- They can be stimulated by:

1- distention

2- specific chemical substances

3-irritation of



Types of Movments

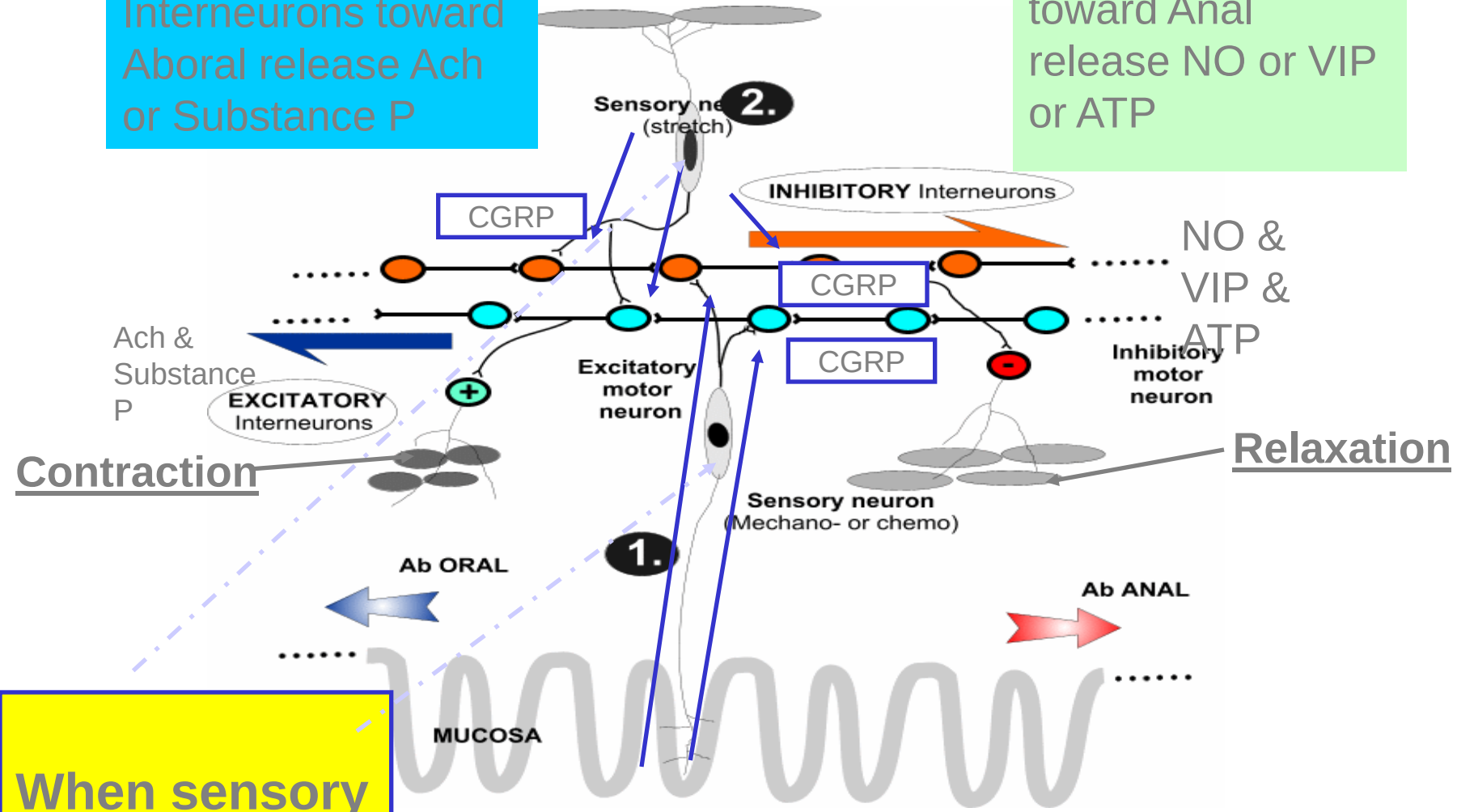
- Propulsive (Propels the materials)

- Mixing (Mixes the materials)

Mechanism of Peristaltic Contraction

Interneurons toward Aboral release Ach or Substance P

Interneurons toward Anal release NO or VIP or ATP



When sensory fibers are stimulated

Hormonal Control of Gastrointestinal Motility

- ***1) Gastrin*** **is secreted by the "G" cells of the *antrum of the stomach* in response to distention of the stomach, the products of proteins, and *gastrin releasing peptide,* which is released by the nerves of the gastric mucosa during vagal stimulation.**
- **The primary actions of gastrin are : (A)*stimulation of gastric acid secretion* (B) *stimulation of growth of the gastric mucosa.***
- ***2) Cholecystokinin*** **is secreted by "I" cells in the *mucosa of the duodenum and jejunum* mainly in response to digestive products of fat, fatty acids, and mono glycerides in the intestinal contents. This hormone strongly contracts the gallbladder, and also inhibits stomach contraction moderately.**

Hormonal Control of Gastrointestinal Motility

- ***3) Secretin*** **was the first gastrointestinal hormone discovered and is secreted by the "S" cells in the *mucosa of the duodenum* in response to acidic gastric juice emptying into the duodenum from the pylorus of the stomach. Secretin has a mild effect on motility of the gastrointestinal tract and acts to promote pancreatic secretion of bicarbonate which in turn helps to neutralize the acid in the small intestine.**
- ***4) Gastric inhibitory peptide*** **is secreted by the *mucosa of the upper small intestine,* mainly in response to fatty acids and amino acids but to a lesser extent in response to carbohydrate. It has a mild effect in decreasing motor activity of the stomach and therefore slows emptying of gastric contents into the duodenum when the upper small intestine is already overloaded with food**

- ***5) Motilin* is secreted by the *upper duodenum* during fasting, and the only known function of this hormone is to *increase gastrointestinal motility.* Motilin is released cyclically and stimulates waves of gastrointestinal motility called *interdigestive myoelectric complexes* that move through the stomach and small intestine**
- **every 90 minutes in a fasted person. Motilin secretion is inhibited after ingestion by mechanisms that are not fully understood.**

Gastrointestinal Reflexes

- ***1) Reflexes that are integrated entirely within the gut wall enteric nervous system.*** Propulsive Movements-Peristalsis,
- 2) ***Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the gastrointestinal tract.***
- **(the *gastrocolic reflex),* (the *enterogastric reflexes* (the *colonoileal reflex).***
- 3) ***Reflexes from the gut to the spinal cord or brain stem and then back to the gastrointestinal tract.***

Gastrointestinal Reflexes

- 3) ***Reflexes from the gut to the spinal cord or brain stem and then back to the gastrointestinal tract.***
- ***(1)(vago-vagal reflex)*** **to control gastric motor and secretory activity;**
- **(2) pain reflexes that cause general inhibition of the entire gastrointestinal tract**
- **(3) defecation reflexes that travel from the colon andrectum to the spinal cord and back again to produce the powerful colonic, rectal, and abdominal**
- **contractions required for defecation .**

GI blood Flow

1) Effect of Gut Activity and Metabolic Factors on Gastrointestinal Blood Flow (oxygen concentration, *adenosine***)**

2) Nervous Control of Gastrointestinal
Stimulation of the parasympathetic nerves *increases local blood flow.*
Sympathetic stimulation, decreased blood flow

3) Possible Causes of the Increased Blood Flow During Gastrointestinal Activity:
1) several vasodilator released from the mucosa of the intestinal tract: CCK-PZ, VIP,, *gastrin,* and *secretin.*
2) *kallidin* and *bradykinin, from Gland.*
3) Hypoxia in the gut wall

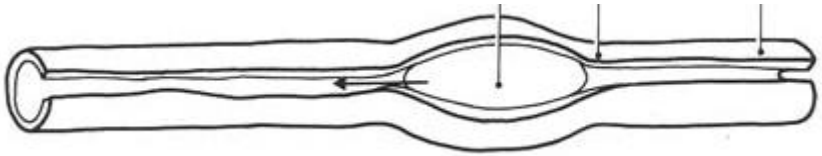
Basic Digestive Processes

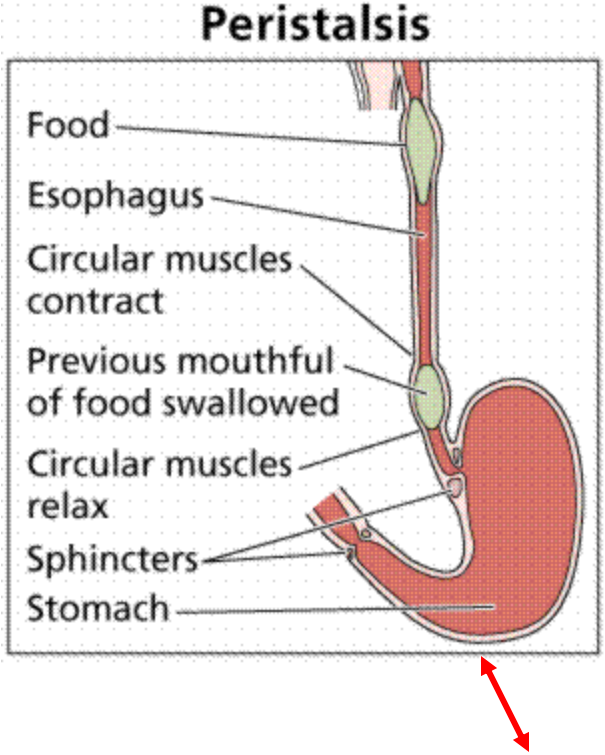
(1) Motility

Muscles in GI tract contract

Mix and move contents

Food Contracted Relaxed





Propulsive movements

Mix with digestive juices - greater digestion

Greater exposal to absorptive surface ↑ absorption

Chewing Reflex

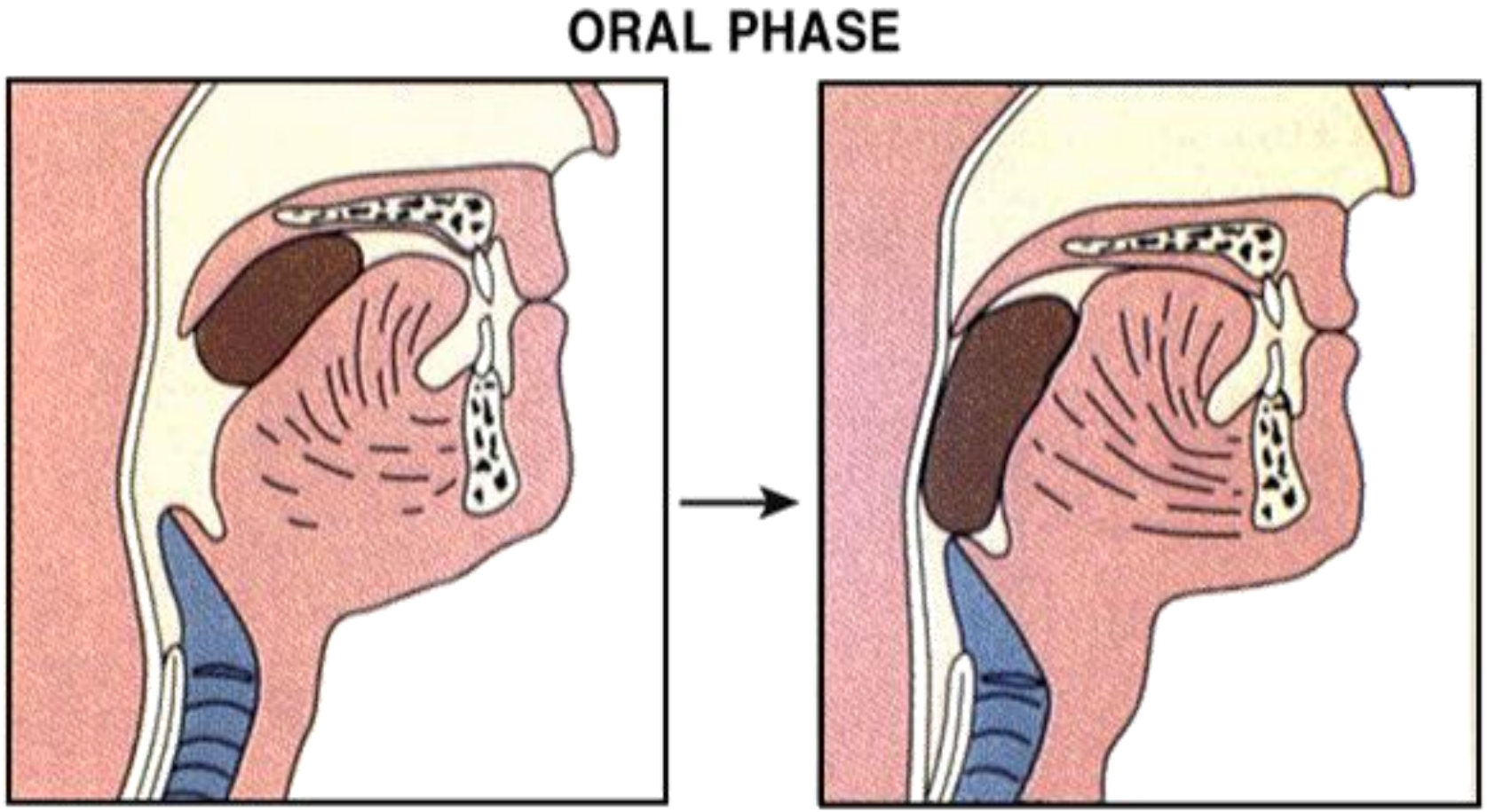
- Food presence ⟷ Reflex inhibition of chewing muscles
- Lower Jaw drops
- This drops initiates a stretch reflex

  ⟷ Jaw muscles contract
- Continues

SWALLOWING

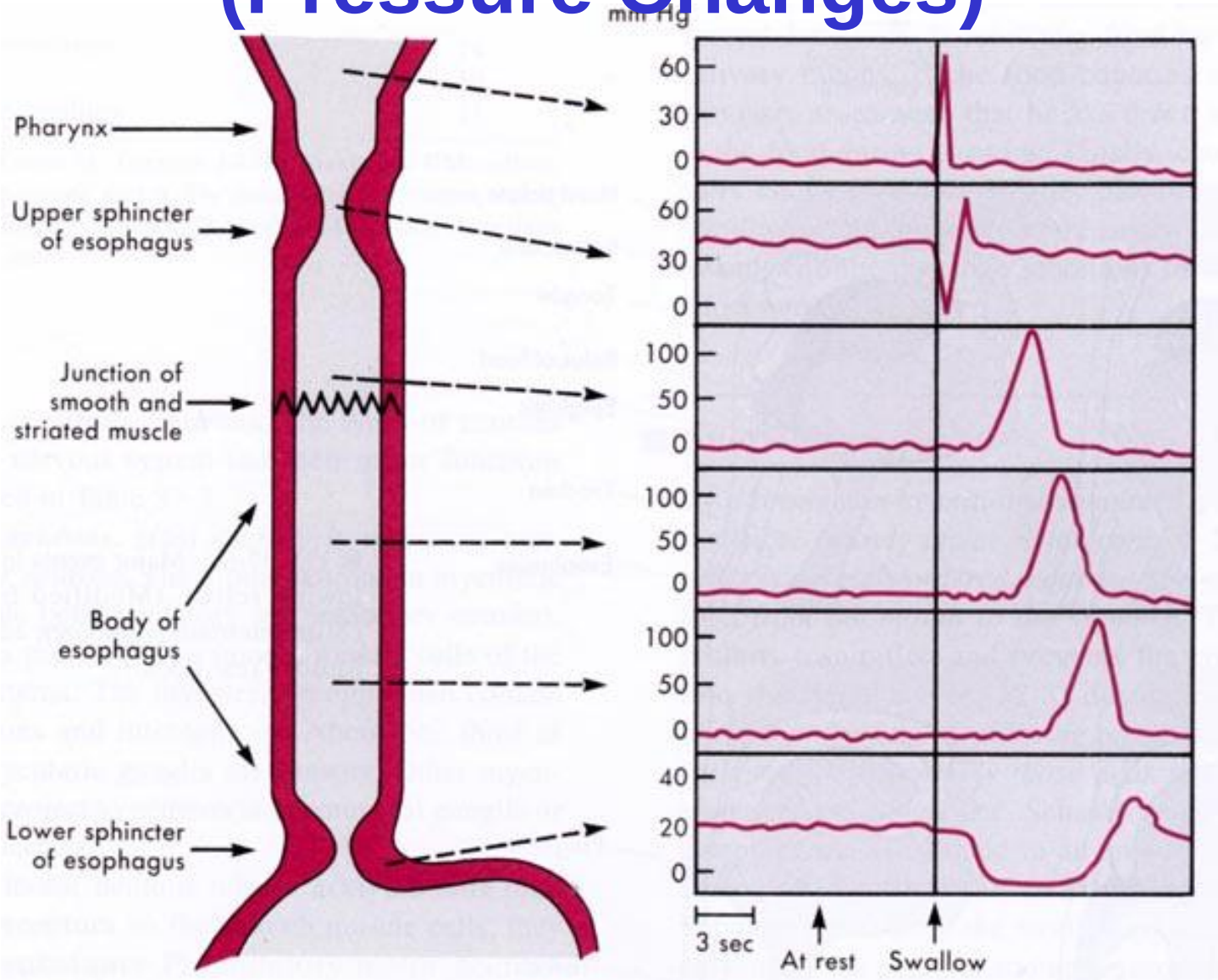
- Oral Phase (voluntarily)
- Pharyngeal Phase (Involuntarily)
- Esophageal Phase (Involuntarily)

SWALLOWING



Once food has been chewed, it is swallowed. When you swallow, a series of reflexes allow food to enter the esophagus and proceed to the stomach (rather than enter the trachea)..

Esophageal Phase of Swallowing (Pressure Changes)



Achalasia

- Problem in opening of LES (defects in release of NO & VIP)

- Treatment

Surgical

Balloon

Botulinum toxin

Stomach

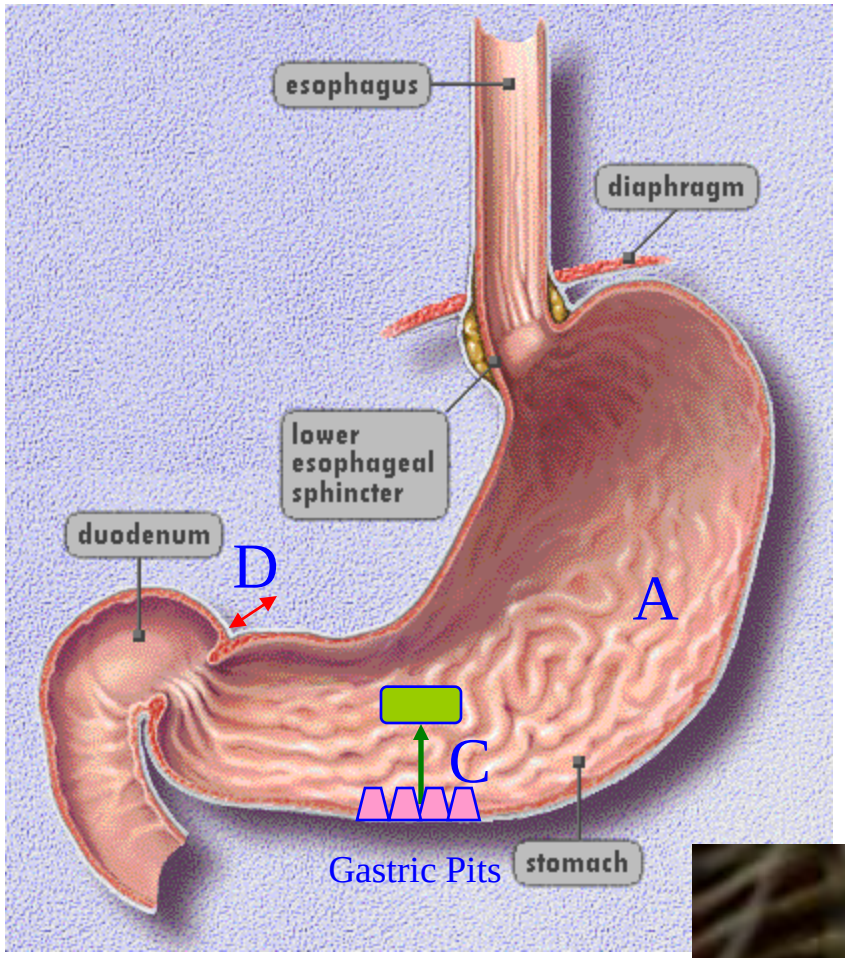
Functions

(A) Storage

(B) Mixing

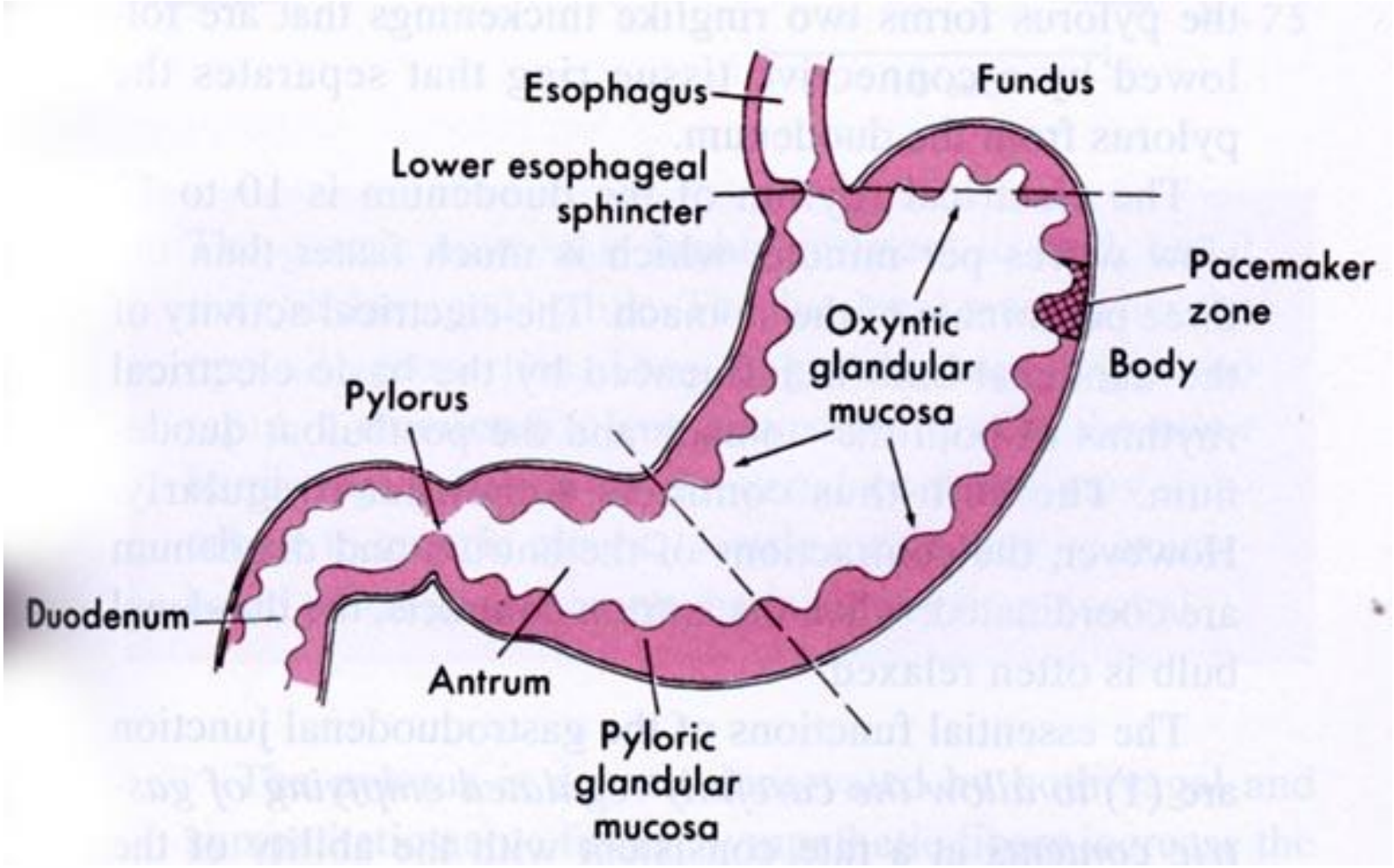
(C) Initiates secretion & digestion

(D) Carefully controls emptying of contents to the Small Intestine



B

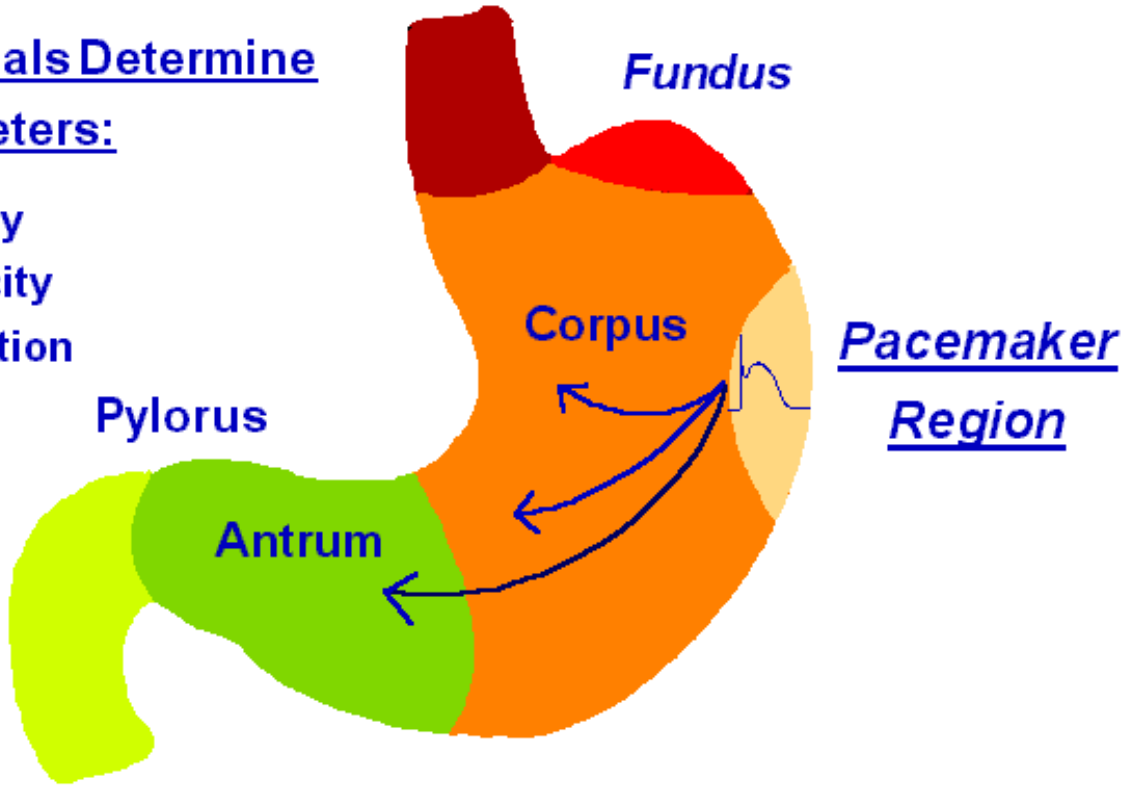
Major Areas of the Stomach



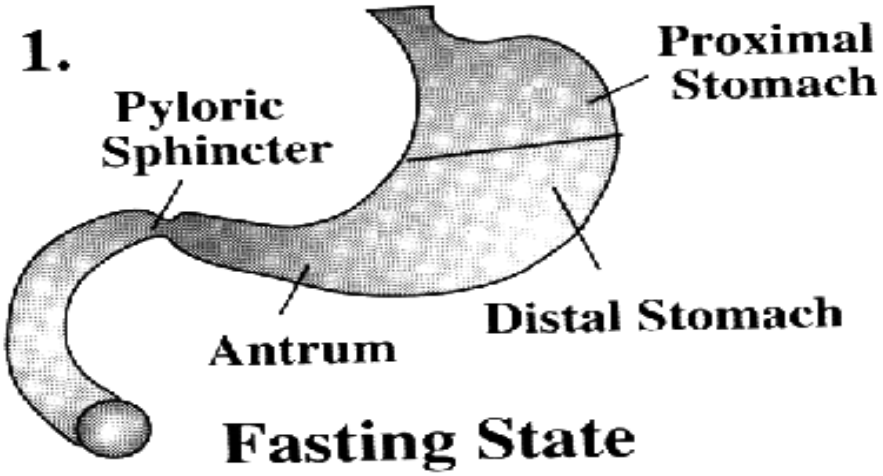
Motor behavior of the stomach is determined by dominant pacemaker in the corpus

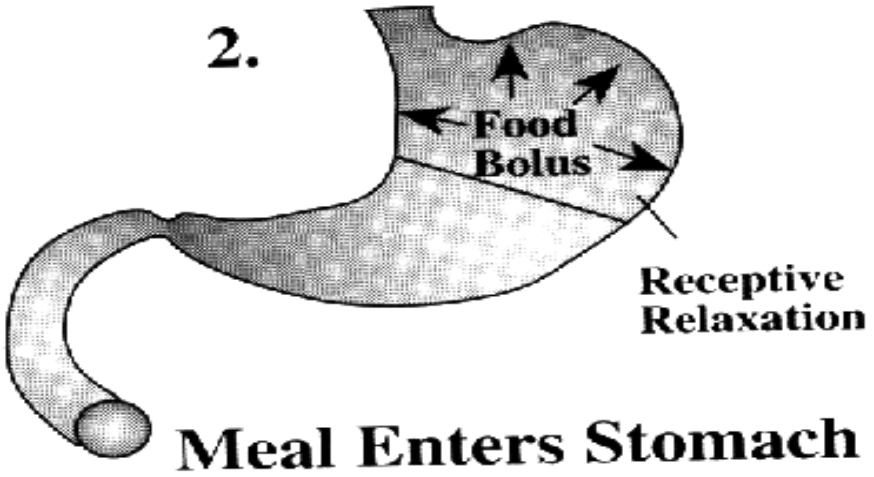
Pacemaker Potentials Determine Contractile Parameters:

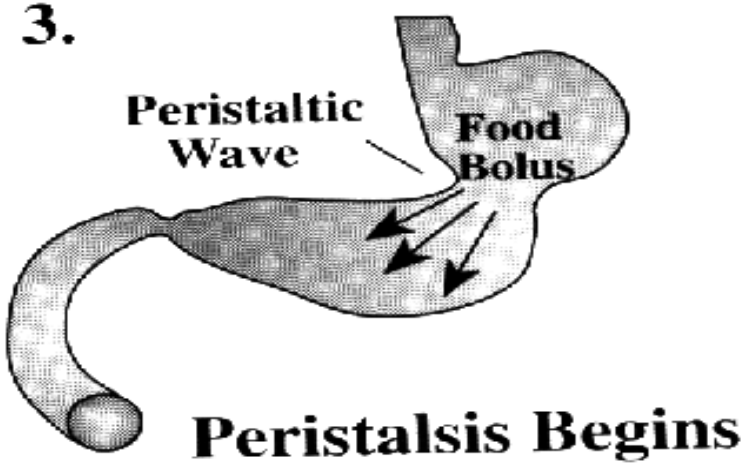
- Maximal Frequency
- Propagation Velocity
- Propagation Direction

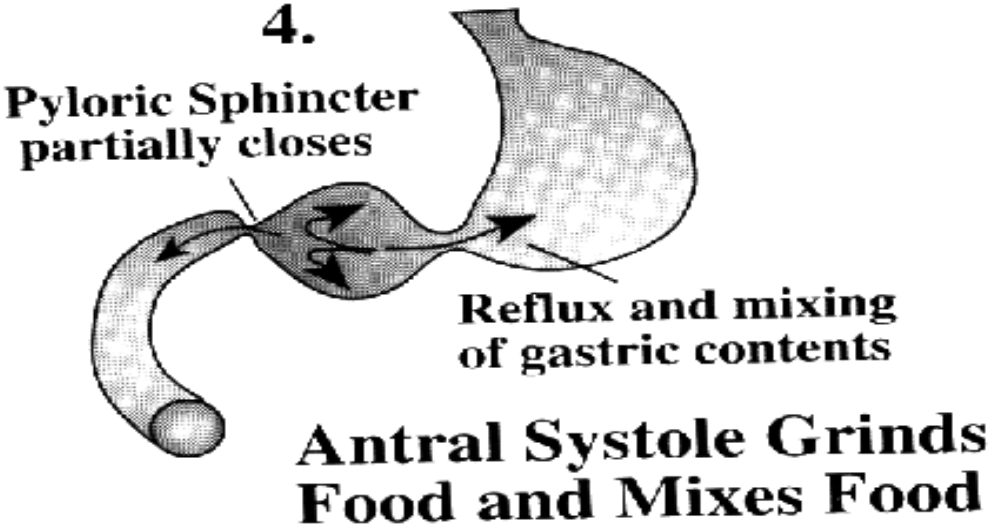


Gastric Motility

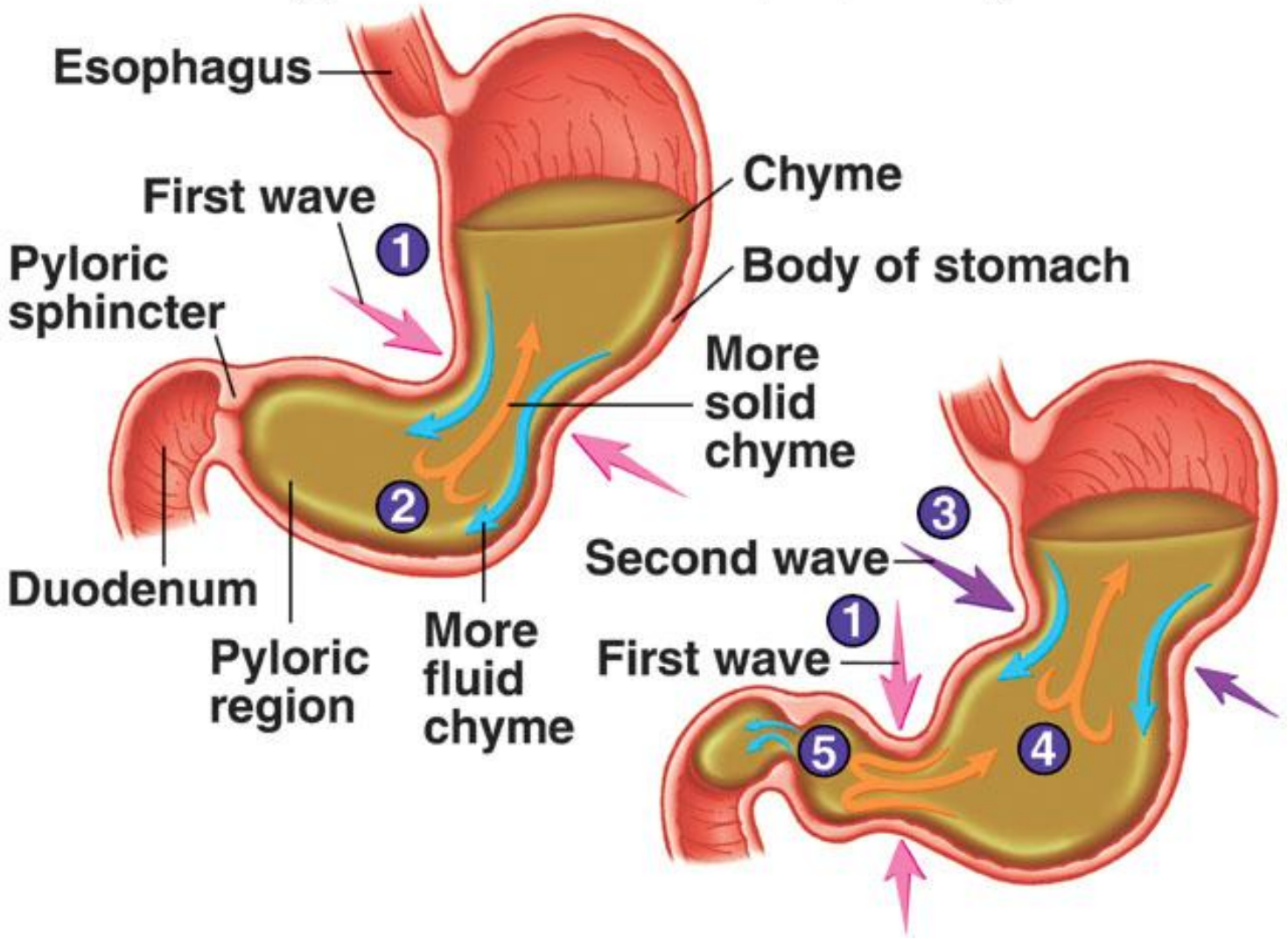








Movements in Stomach



Types of Motility

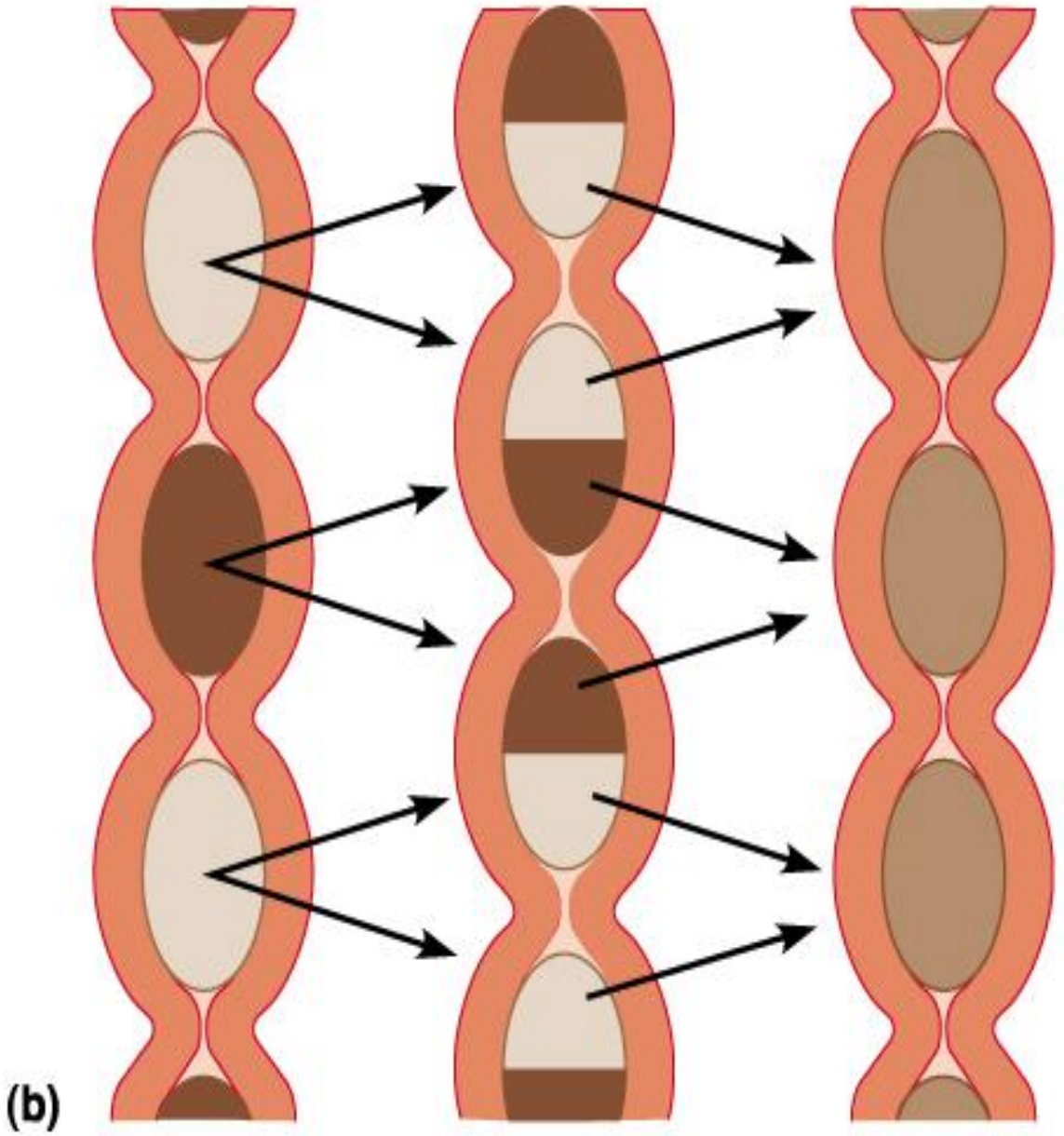
- Mixing movement (Segmental contractions)
- Propulsive movements

SEGMENTATION

In stomach it is 3 contraction per minute

In Duodenum it is 12 contraction per minute

In Jejunum it is 12 contraction per minute

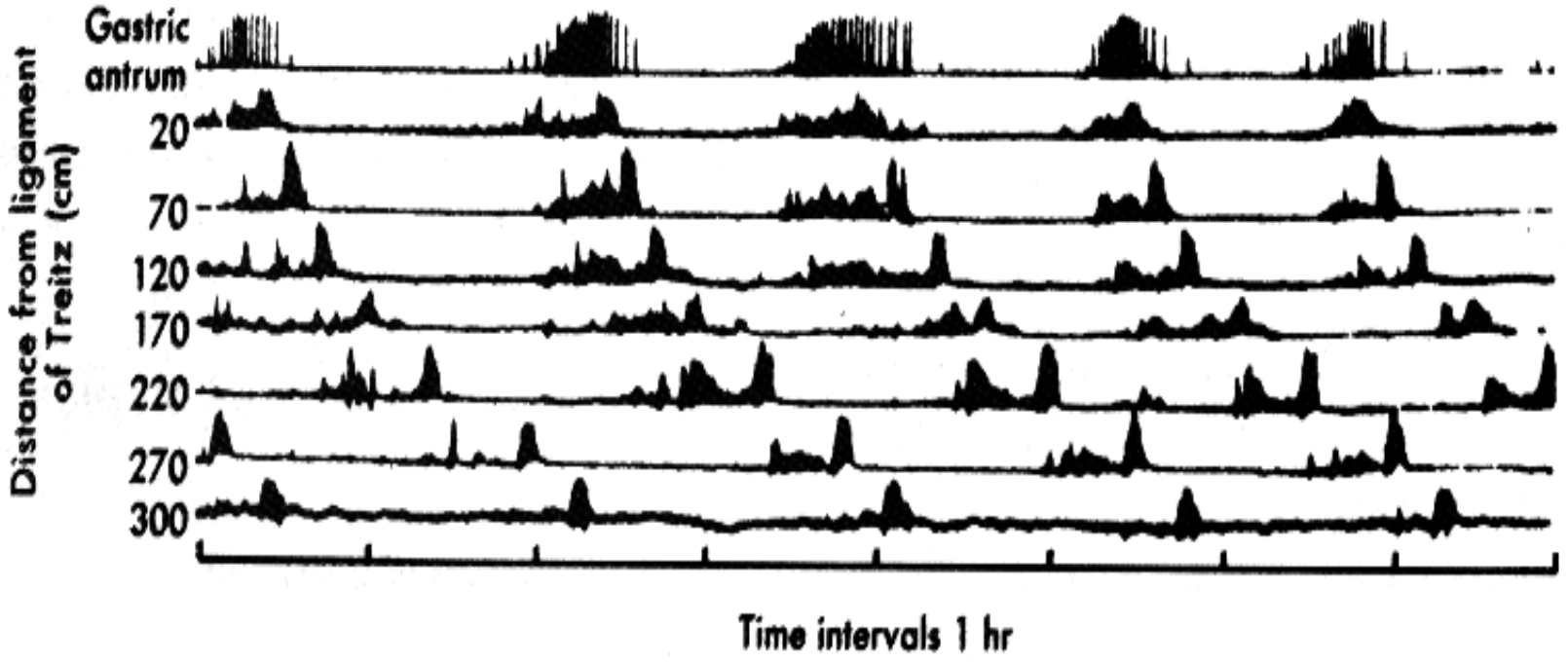


Peristaltic Rush

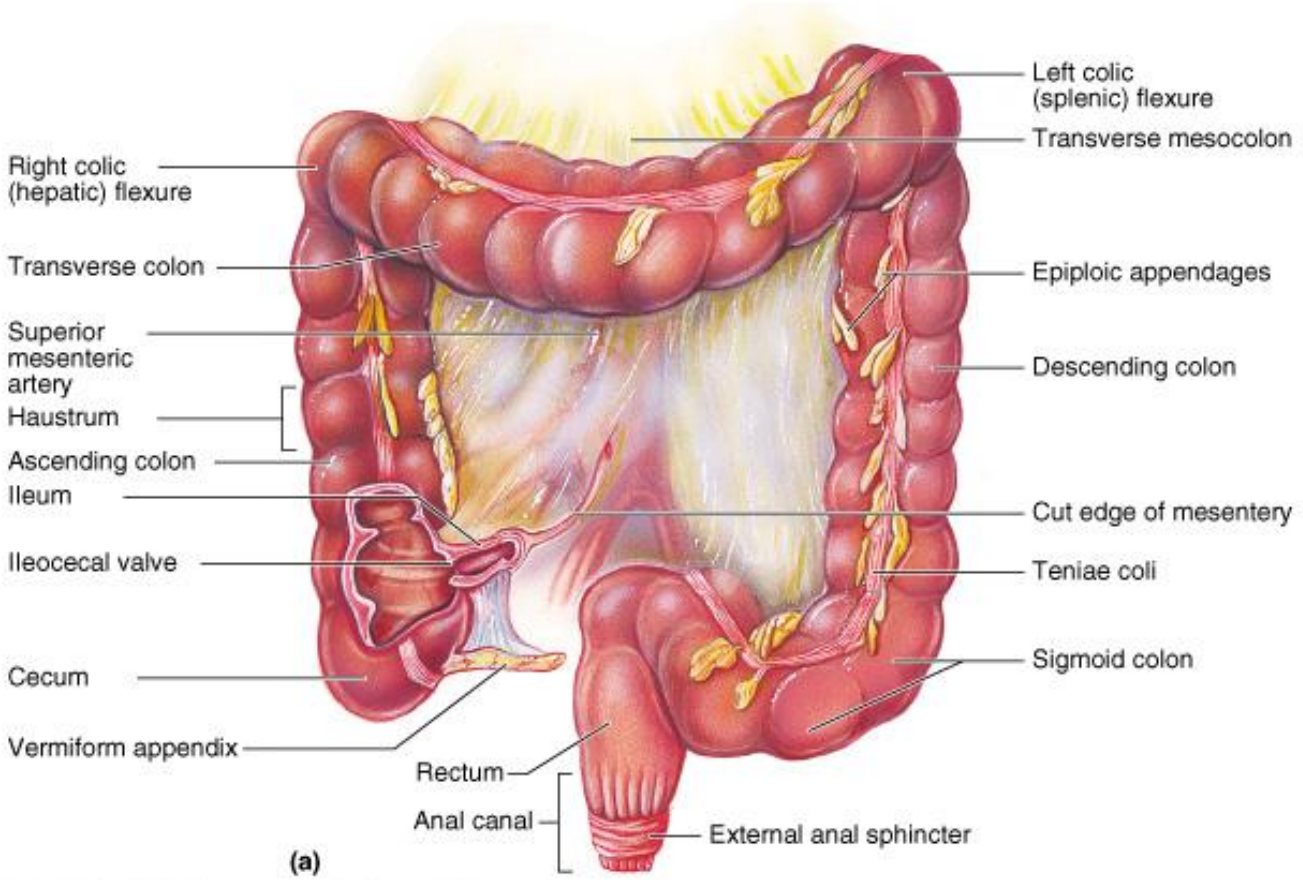
- Powerful peristalsis
- Irritation of intestinal mucosa by Infectious diarrhea
- Partly by extrinsic nervous reflexes to the brain stem and back again to the intestine and partly by potentiation of intrinsic myentric reflexes

Migrating Motor Complex

- From Stomach to the end of illeum
- Every 75- 90 min
- After processing of the last food



Colon



Function : Absorption of water & electrolyte

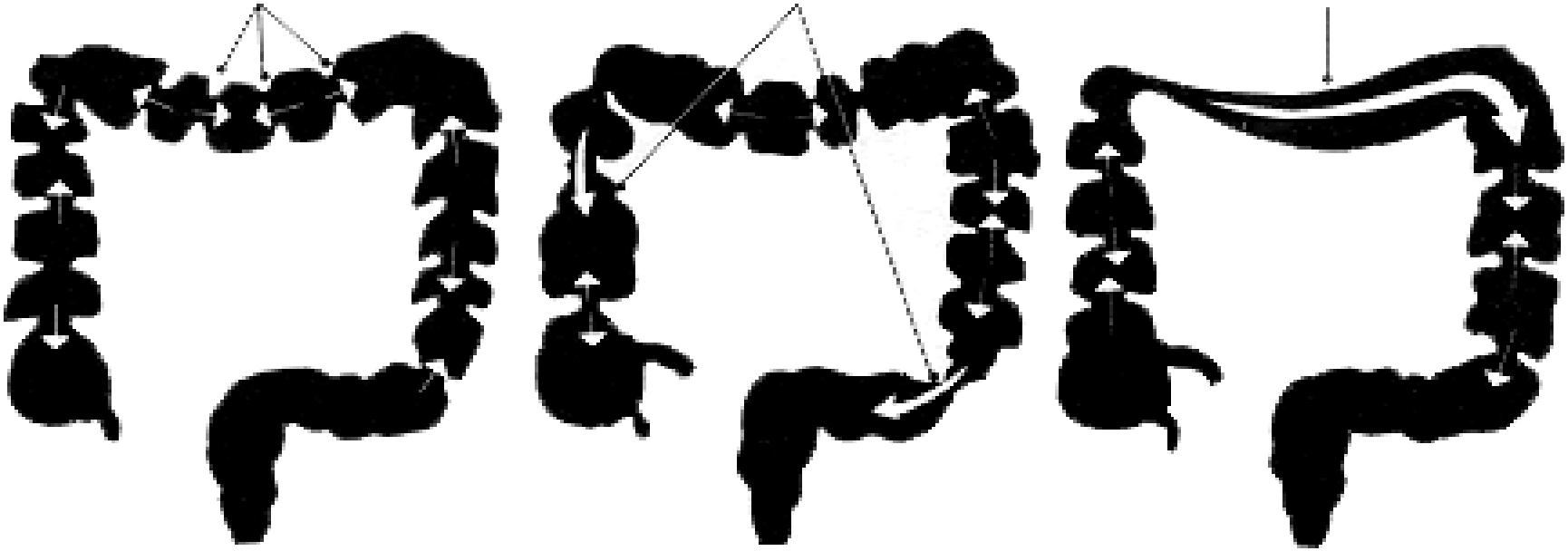
Reservior

Types of Colonic Motility

- Mixing movement (Segmental contractions)
- Propulsive movements (Mass contraction)

Mixing movement
(Haustra contractions)

They help absorption

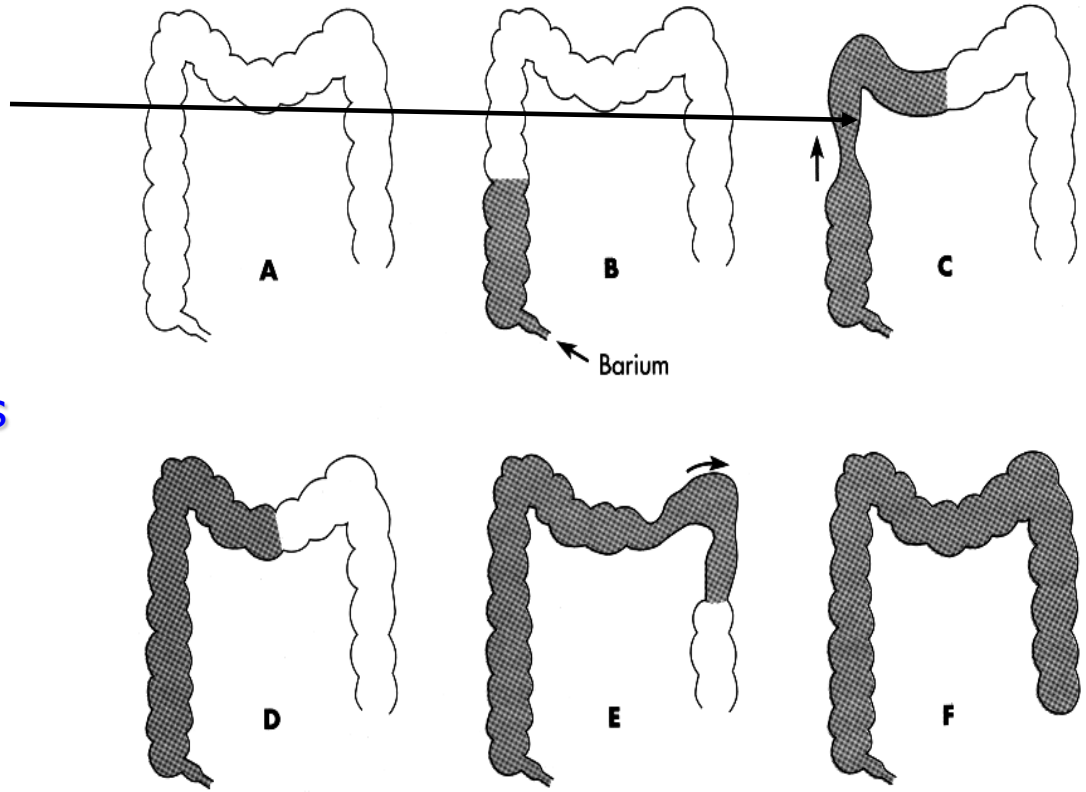


Mass Movements

In most cases
15 min after
breakfast

1- a contracted ring in transverse colon

2- 20 Cm after the contracted ring losses its haustra and contract simultaneously

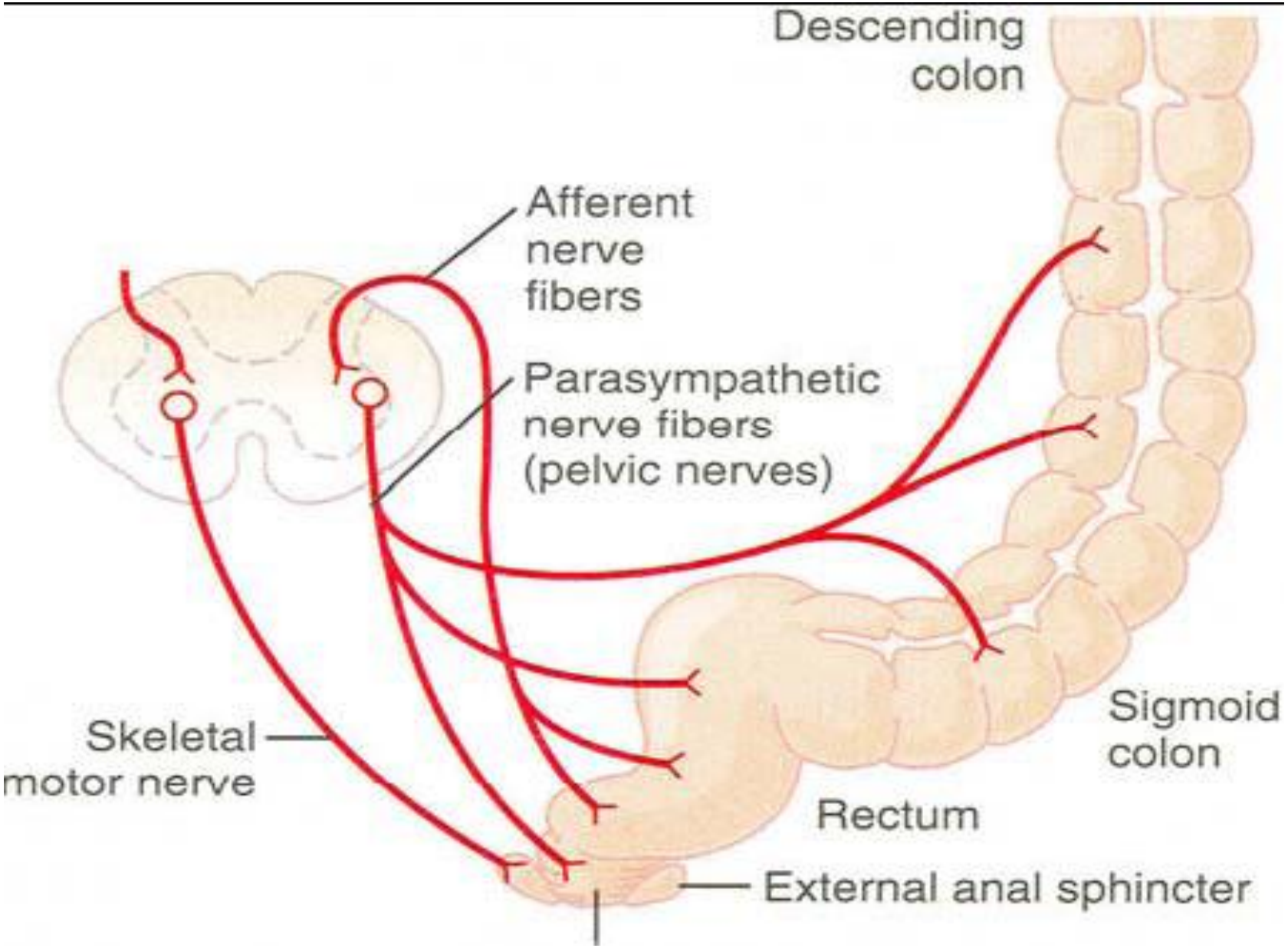


Propulsive movements (Mass contraction)

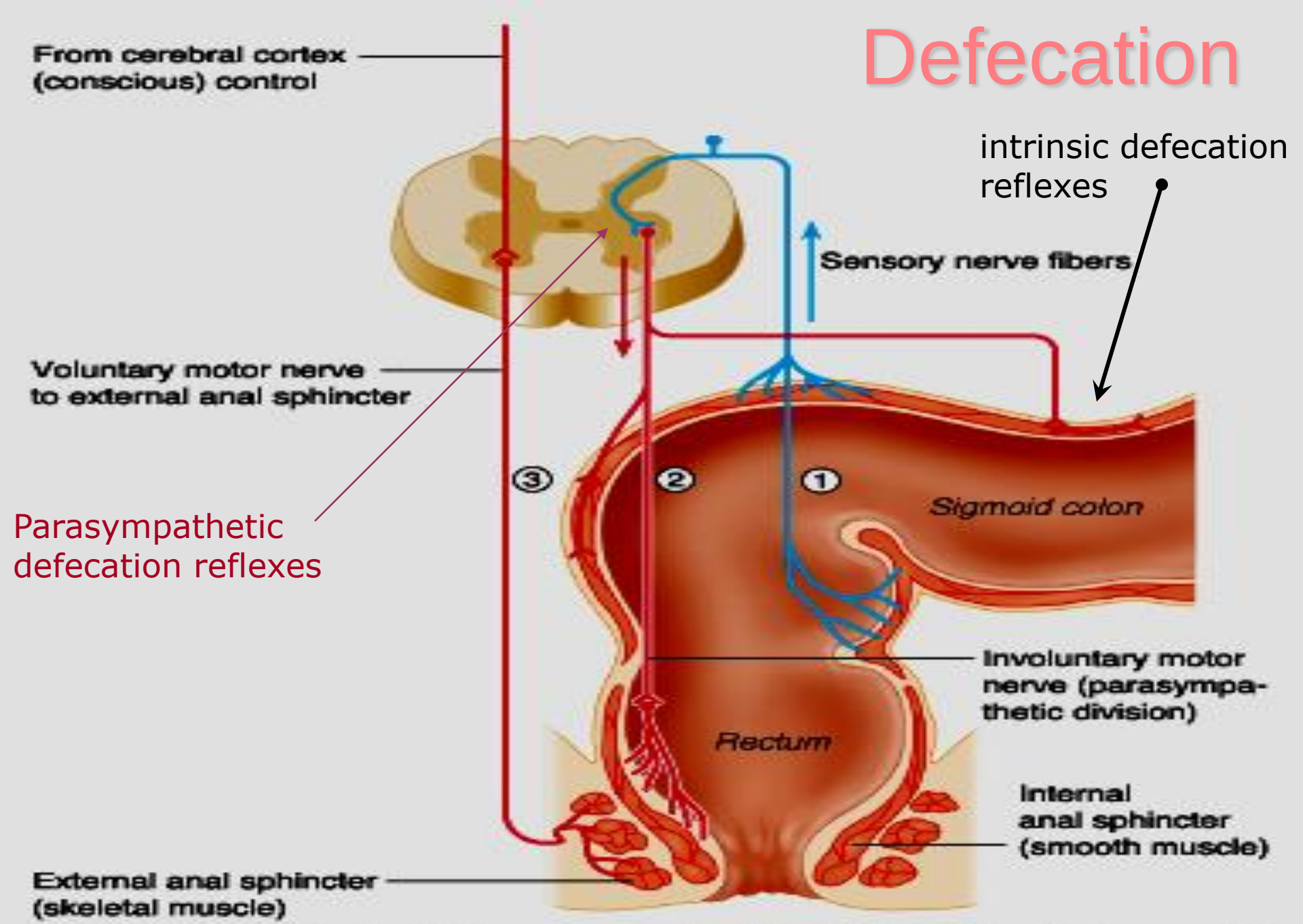
- Gastrocolic and Duodenocolic reflexes facilitate mass movement appearance after meals
- If extrinsic autonomic nerves are dissected these movement disappear
- Irritation of colon can also brings about mass movement

Defecation

- Is initiated by defecation reflexes
- 1- intrinsic defecation reflexes
- 2- Parasympathetic defecation reflexes


Descending colon
Afferent nerve fibers
Parasympathetic nerve fibers (pelvic nerves)
Skeletal motor nerve
Sigmoid colon
Rectum
External anal sphincter

Defecation



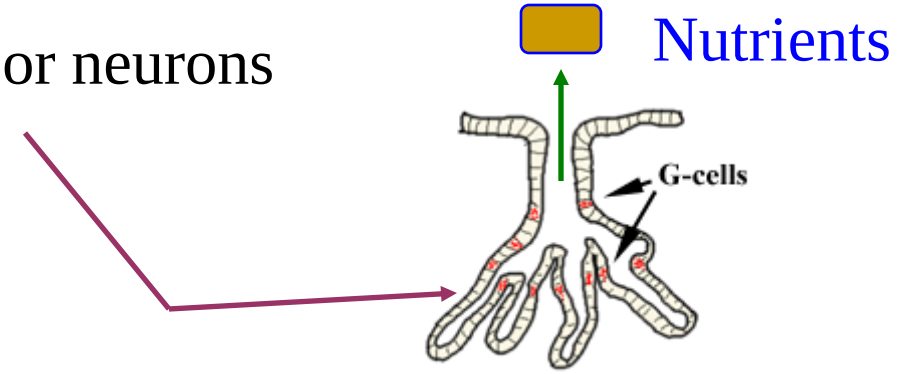
(2) Secretion

Many digestive juices are secreted into the digestive tract by glands along the route.

Contain water, electrolytes and enzymes, bile salts, mucous etc.

Act on nutrients or start/stop other substances acting on the nutrients

Released in response to hormones or neurons



Glands in stomach

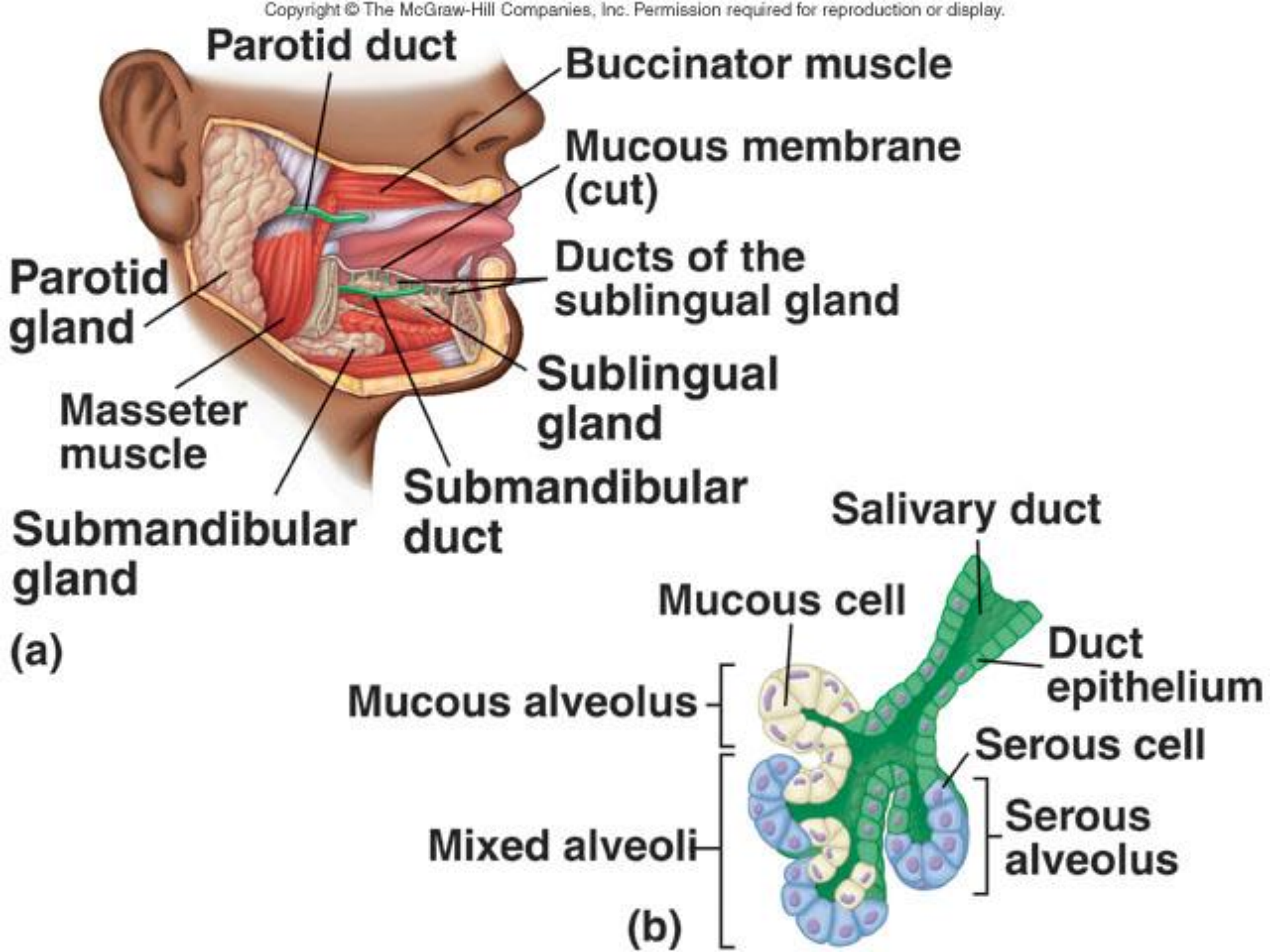
Salivary Secretion

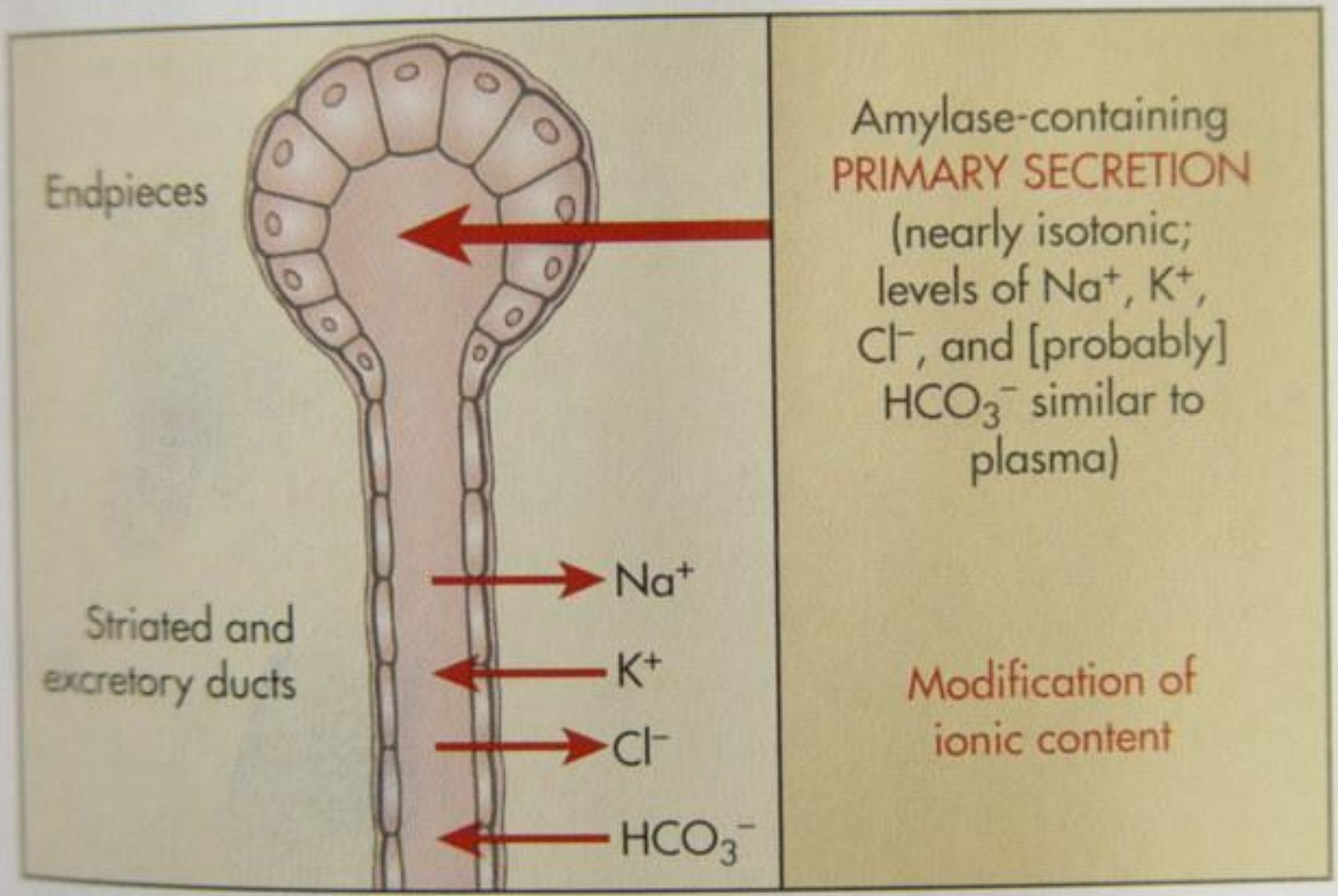
- FUNCTIONS:

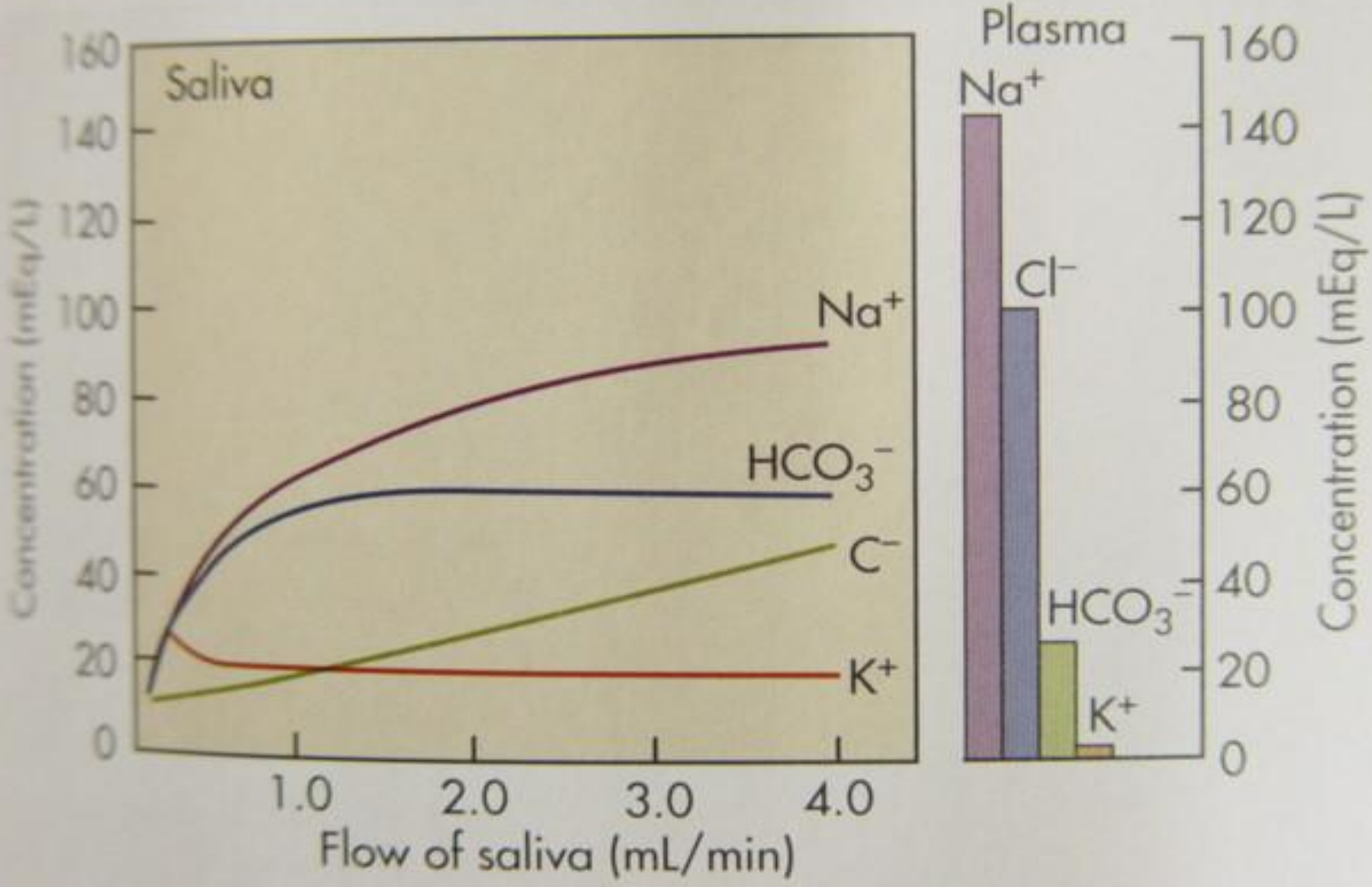
Lubrication & Protection (Mucus)
Digestion (alpha amylase)
Speech
Tasting
Defense (IJA & Lysozym)

- GLANDS: Parotid, Submandibular, Sublingual

- FUNCTIONAL UNIT: Salivon




Endpieces
Striated and excretory ducts
Na+
K+
Cl−
HCO3−
Amylase-containing PRIMARY SECRETION (nearly isotonic; levels of Na+, K+, Cl−, and [probably] HCO3− similar to plasma)
Modification of ionic content

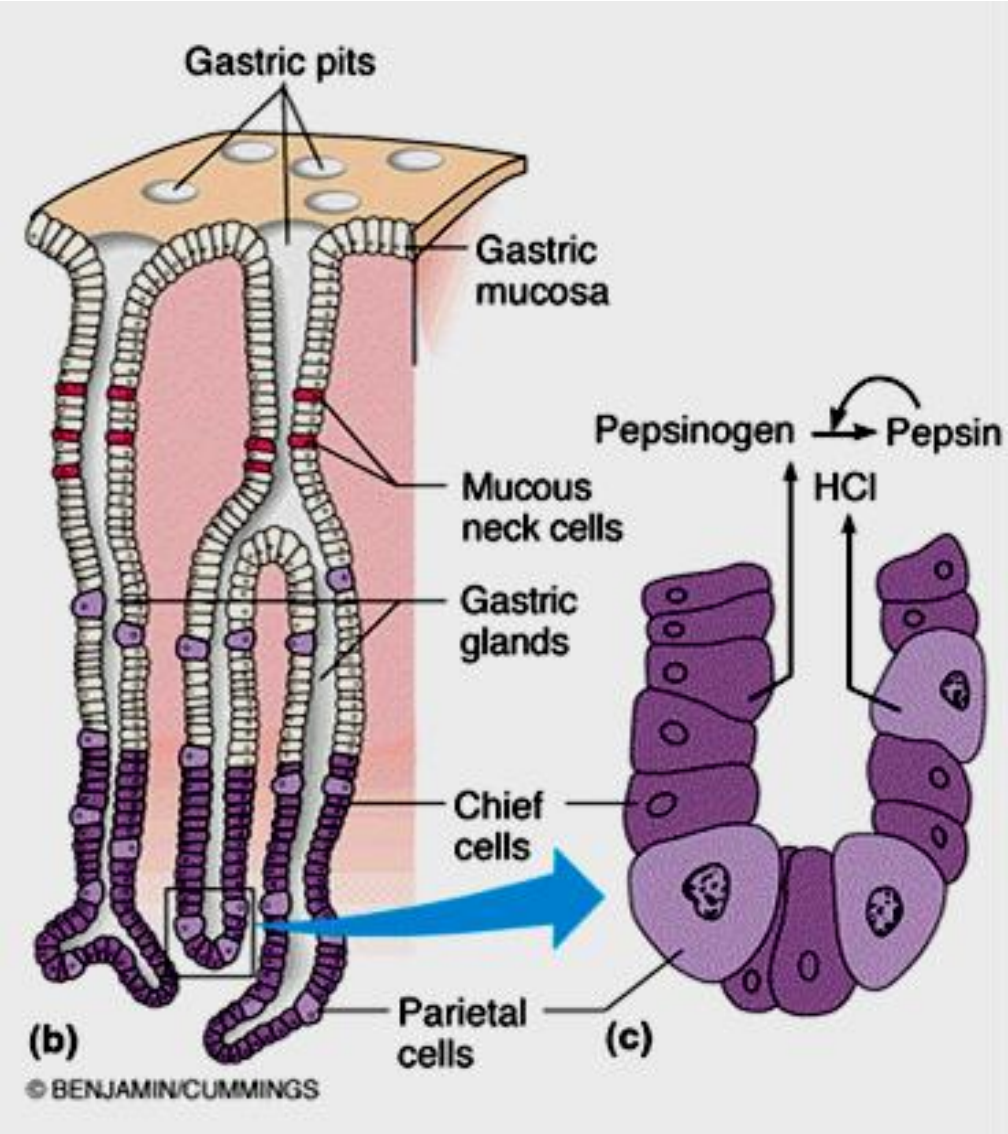

Saliva
Plasma
Na+
Cl−
HCO3−
K+
C−
160
140
120
100
80
60
40
20
0
Concentration (mEq/L)
1.0
2.0
3.0
4.0
Flow of saliva (mL/min)

Gastric Secretion

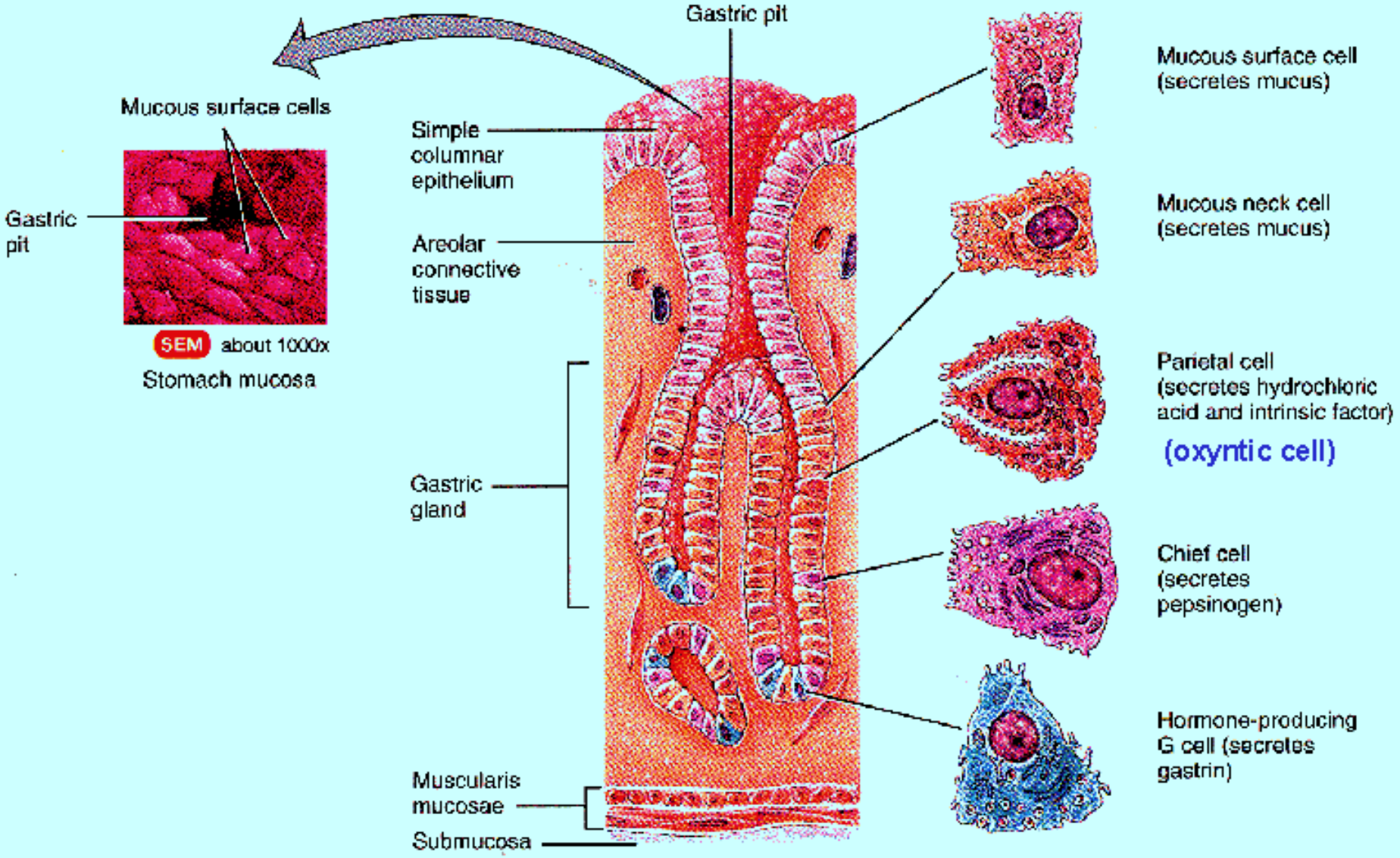
- Acid (Kills bacteria & Changes inactive Pepsinogen to active form and digest protein)
- Mucus (protection)
- Bicarbonte (protection)
- Pepsinogen (enzyme)
- Intrinsic Factor (Vit B12 absorption)

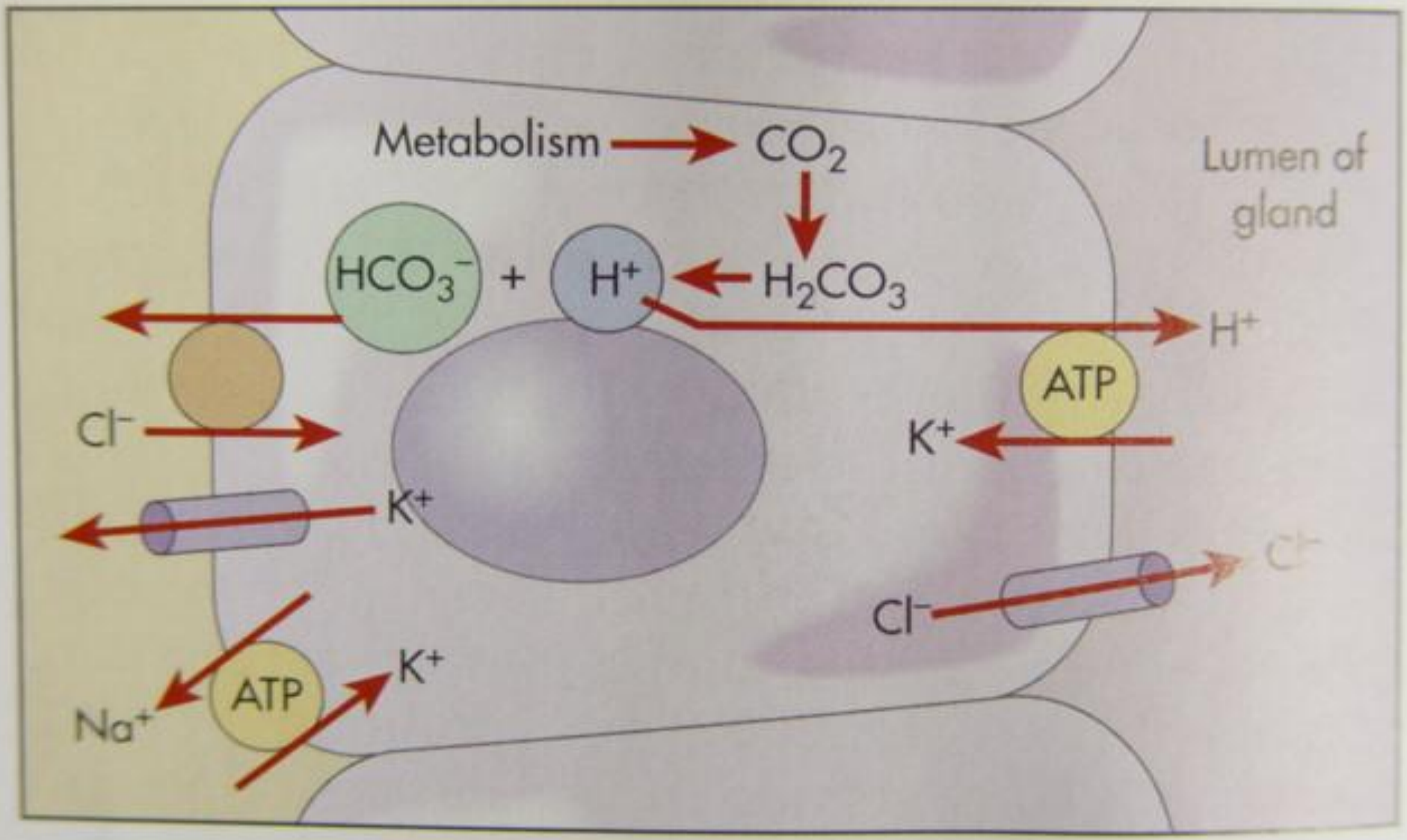
Microscopic Anatomy

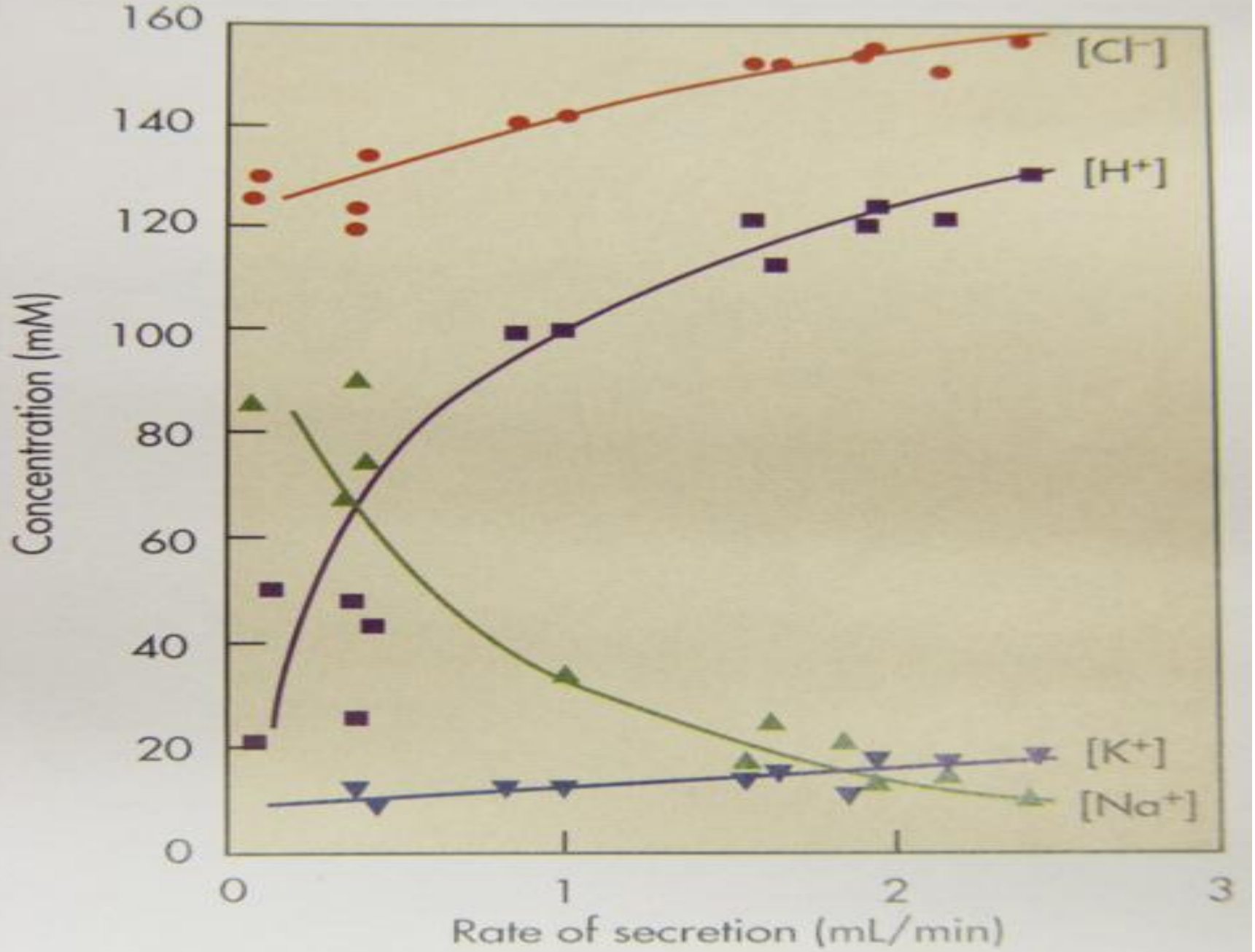
- The otherwise smooth lining is dotted with millions of gastric pits which lead to gastric glands that produce gastric juice
- The glands of the stomach body are substantially larger and produce the majority of the stomach secretions

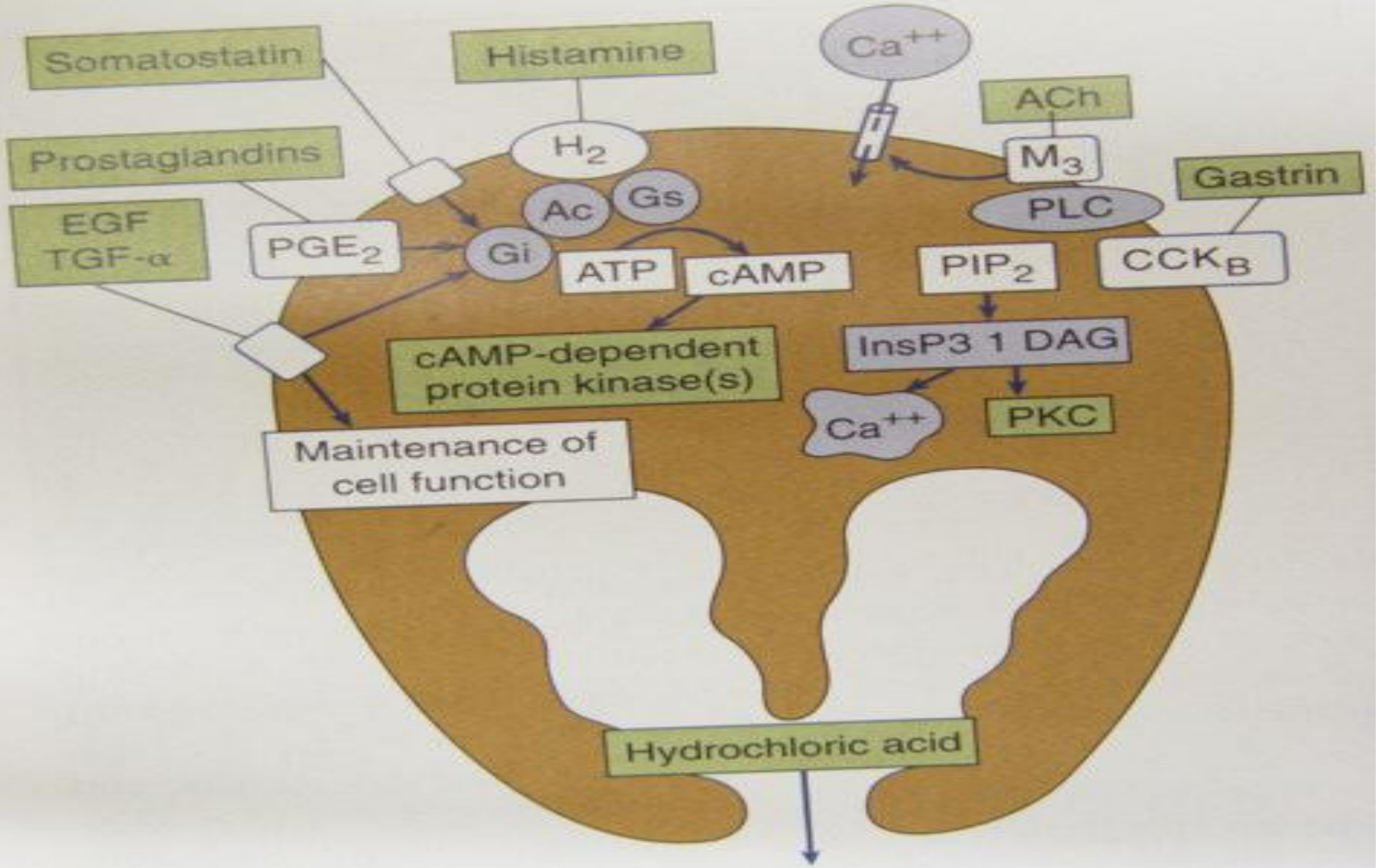


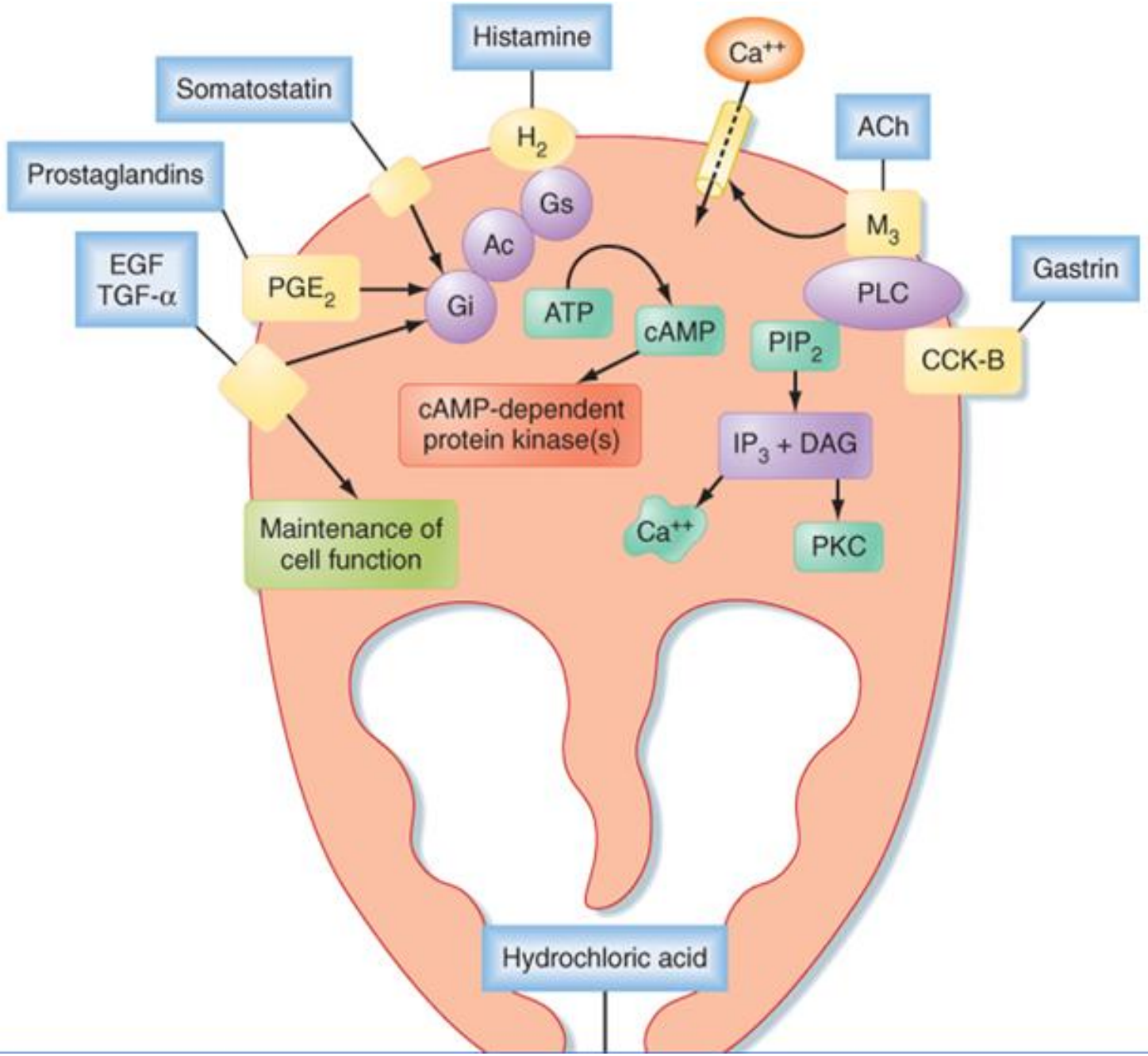
Gastric Gland ⇒ Gastric Pit




Metabolism
CO_2
Lumen of gland
HCO_3^-
+
H^+
H_2CO_3
H^+
ATP
Cl^-
K^+
K^+
Cl^-
Cl^-
K^+
ATP
Na^+


160
140
120
100
80
60
40
20
0
Concentration (mM)
[Cl⁻]
[H⁺]
[K⁺]
[Na⁺]
0
1
2
3
Rate of secretion (mL/min)


Somatostatin
Histamine
Ca++
ACh
Prostaglandins
H2
M3
Gastrin
EGF
TGF-α
Ac
Gs
PLC
PGE2
Gi
ATP
cAMP
PIP2
CCKB
cAMP-dependent
protein kinase(s)
InsP3 1 DAG
Ca++
PKC
Maintenance of
cell function
Hydrochloric acid


Histamine
Ca++
Somatostatin
H2
ACh
Prostaglandins
Gs
Ac
M3
EGF
TGF-α
PGE2
Gi
ATP
cAMP
PLC
Gastrin
PIP2
CCK-B
cAMP-dependent
protein kinase(s)
IP3 + DAG
Maintenance of
cell function
Ca++
PKC
Hydrochloric acid

cephalic

- 1- Vagus via parasympathetic (Ach)

Gastric Phase

- Presence of food in stomach
- 1- Distention ⟶ central (vagovagal) & local reflexes ⟶ Ach & Gastrin
- Amino acid & peptide ⟹ Gastrin

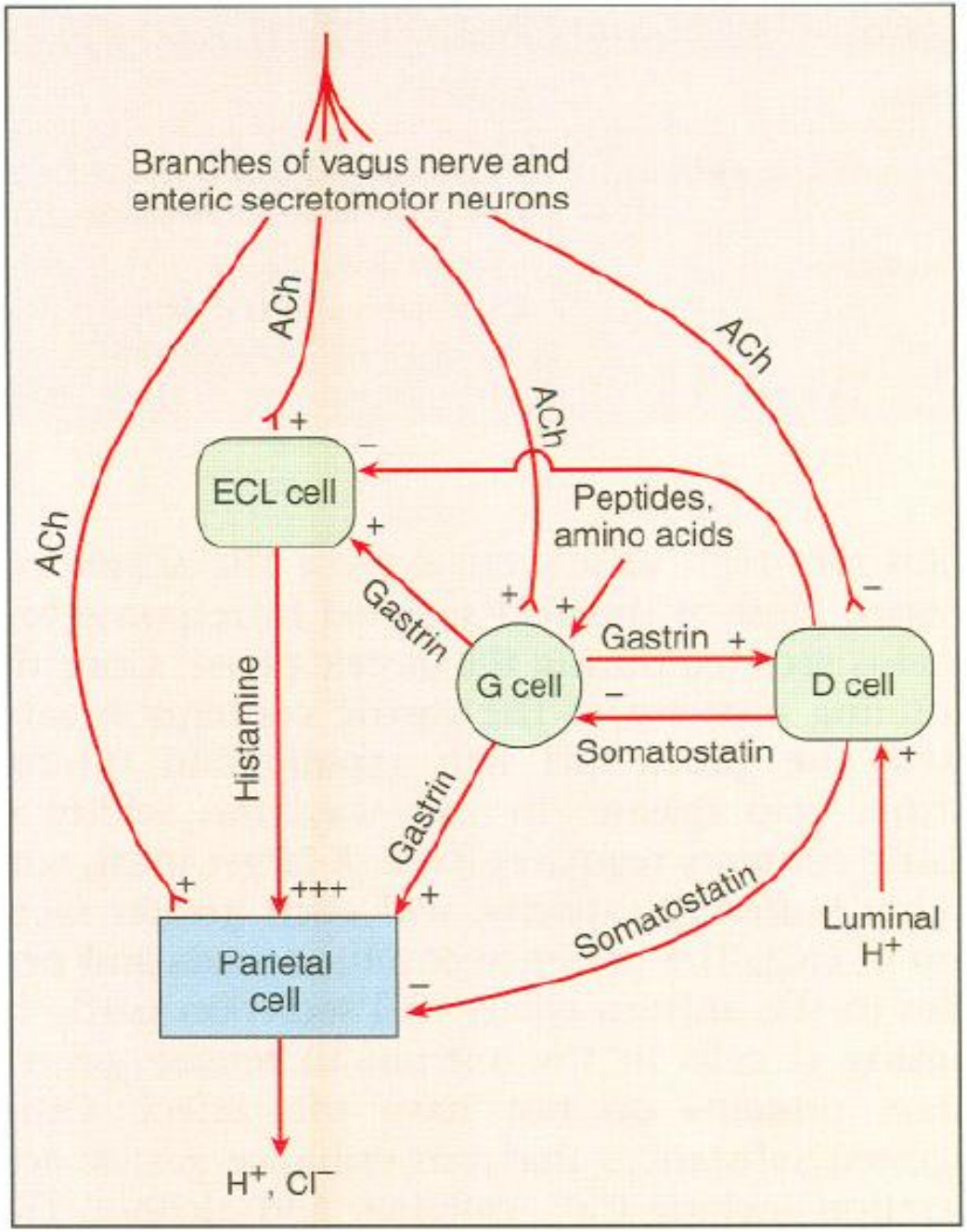


FIGURE 34–10. Control of gastric secretion of HCl. His-

Intestinal Phase

- At first PH>3
- Then PH<3

TABLE 34–1. MECHANISMS FOR STIMULATION OF GASTRIC ACID SECRETION

Phase	Stimuli	Mechanisms of Stimulation of HCl Secretion
Cephalic	Chewing, swallowing, taste, smell of food	Vagal impulses excite enteric secretomotor neurons to parietal, G, and ECL cells
Gastric	Gastric distention	Local and vagovagal reflexes stimulate parietal cells and release of histamine and gastrin
	Peptides and amino acids in lumen	Peptides and amino acids release gastrin from G cells in stomach
Intestinal	Protein digestion products in duodenum	Release of gastrin from G cells in intestine and enterooxyntin
	Distention of duodenum	Enteric and vagovagal reflexes to ECL, G, and parietal cells
	Amino acids and peptides in blood	Release of gastrin from G cells in stomach

Gastric Pits

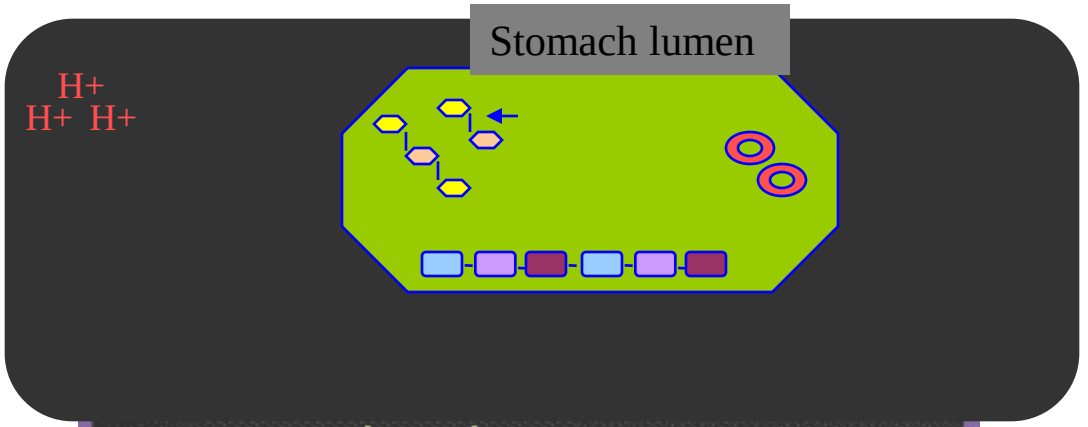
Acidic Environment

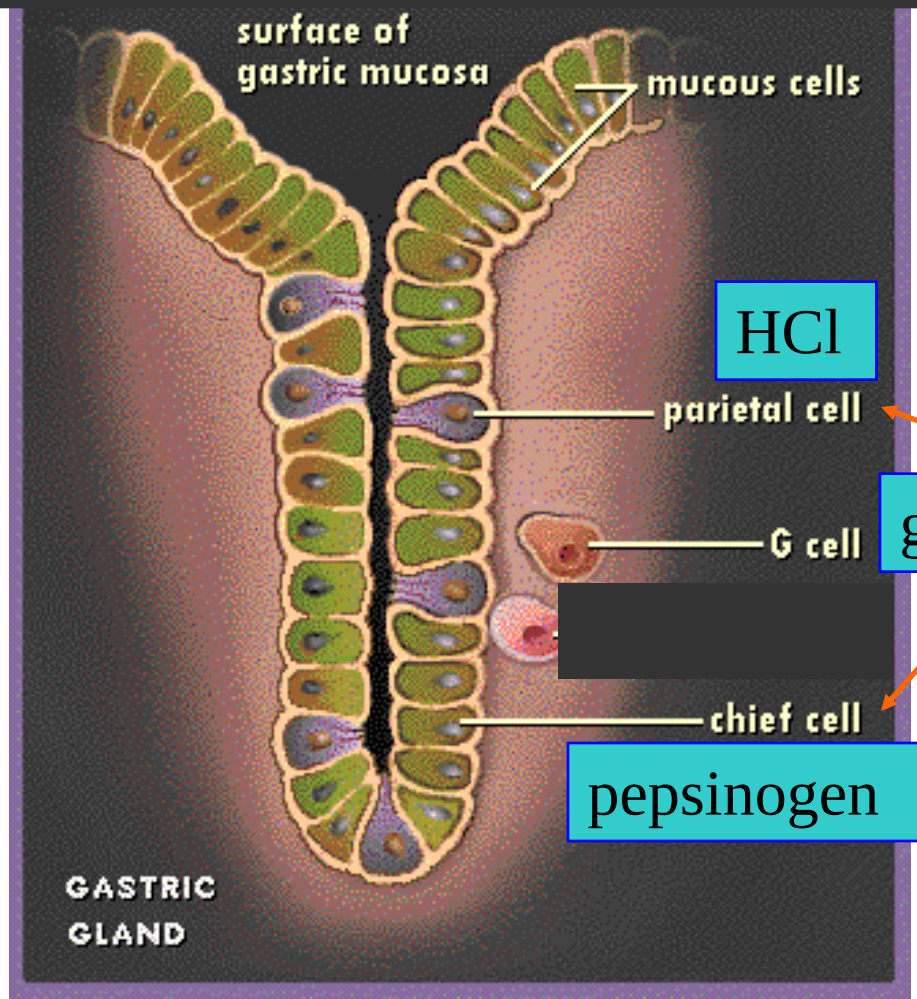
pepsinogen

pepsin

protein

peptides





HCl

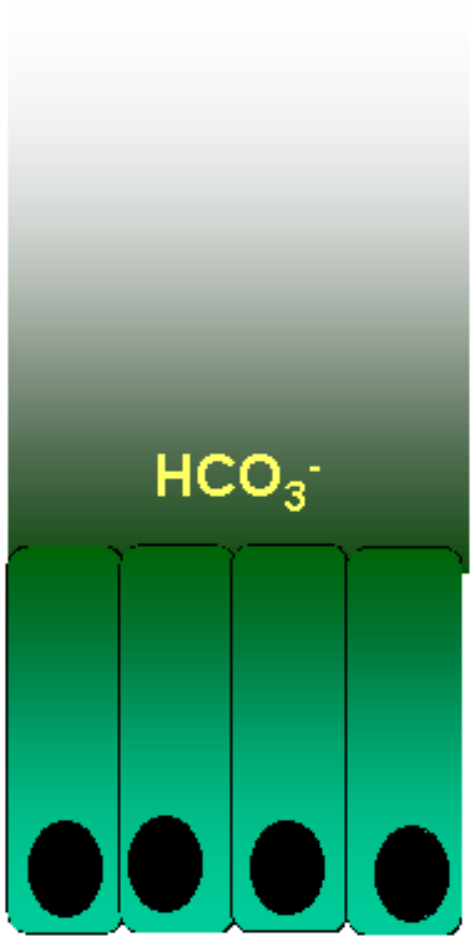
gastrin

pepsinogen

Gastric secretions

- **Mucus**

pH<2



pH7

Physical/chemical barrier to attack by gastric juice

Stimulated by:

•Ach

•Mechanical stim

•Chemicals (ethanol)

If breached e.g. hypersecretion of acid → ulceration

Causes:

1. High acid and peptic content 2. Irritation
3. Poor blood supply
4. Poor secretion of mucus
5. Infection, *H. pylori*

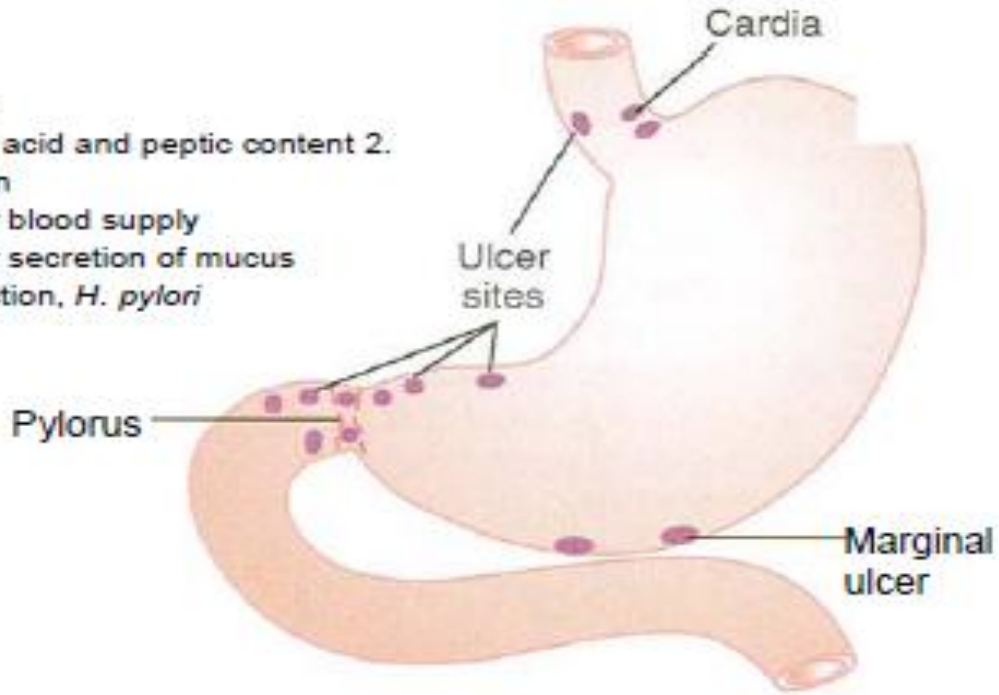


Figure 66–1

Peptic ulcer. *H. pylori, Helicobacter pylori.*

When the stomach contents are emptied into small intestine they are mixed with the secretions from the

pancreas and **liver**

that are emptied at the beginning of the small intestine (duodenum)

Pancreas

Pancreatic secretions

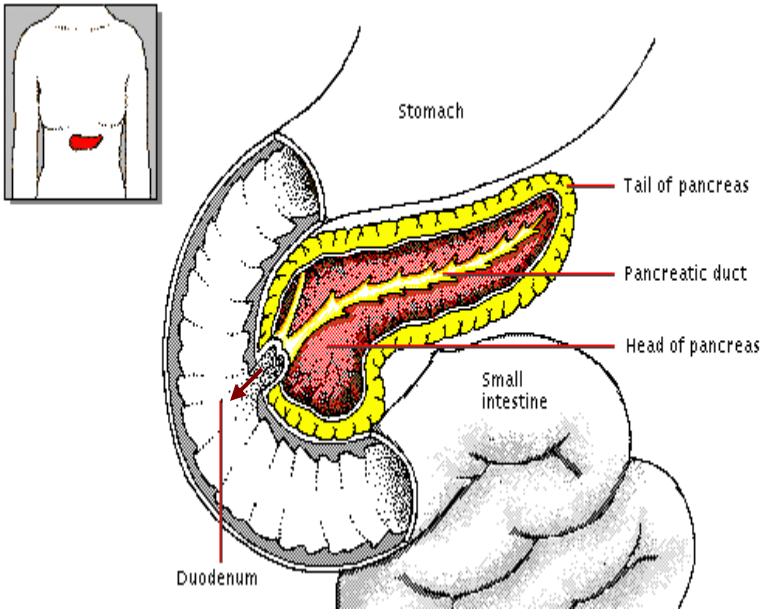
(1) Enzymes

Trypsin

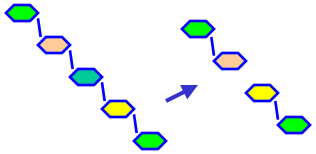
Chymotrypsin

Carboxipeptidase

Breakdown peptides

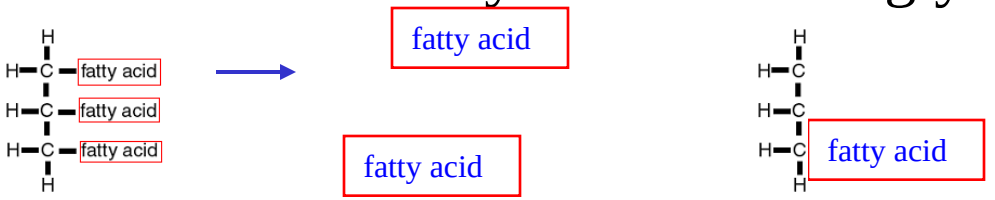


Amylase



Lipase

ONLY enzyme that digests FAT - Free fatty acids + Monoglycerides



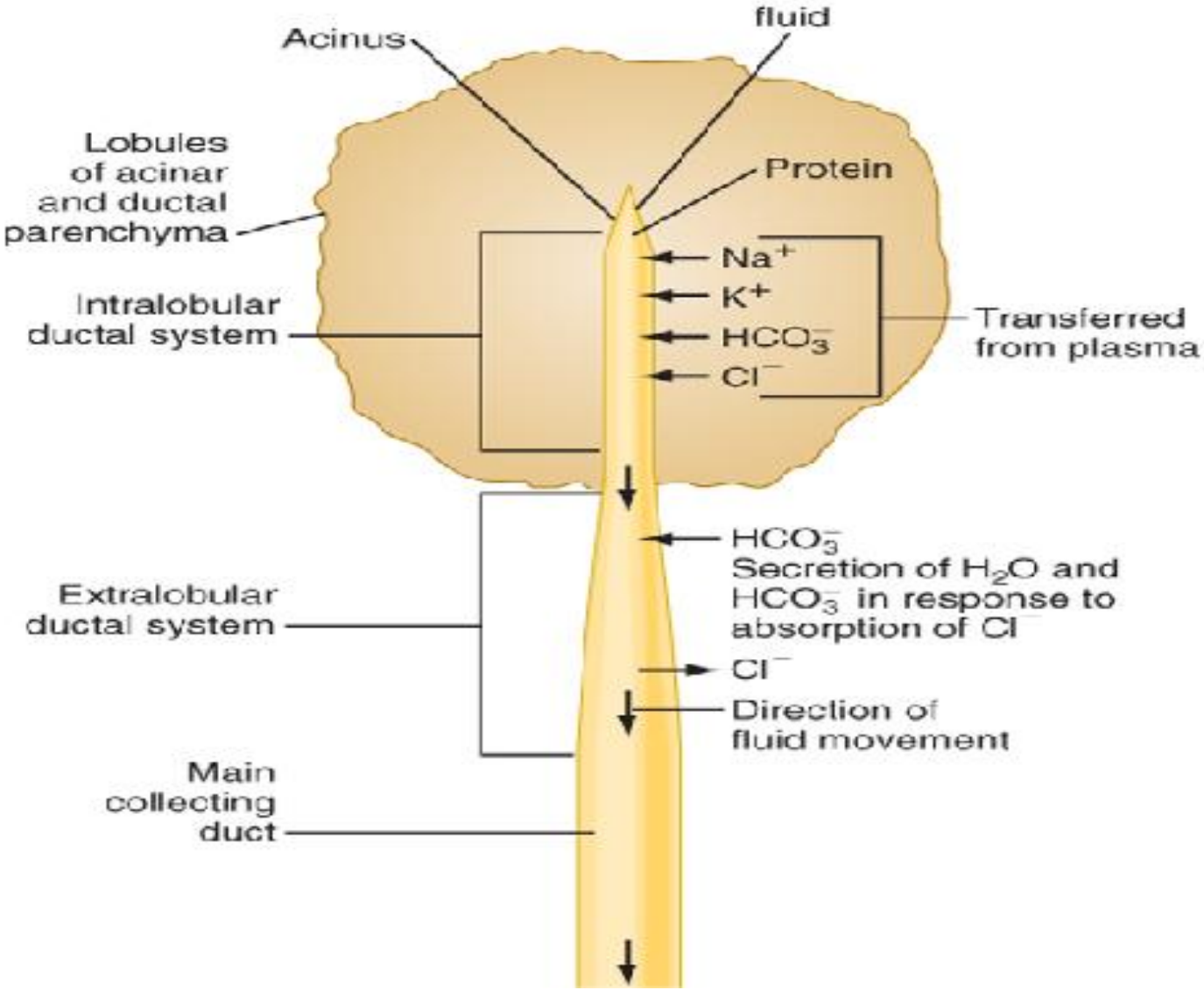


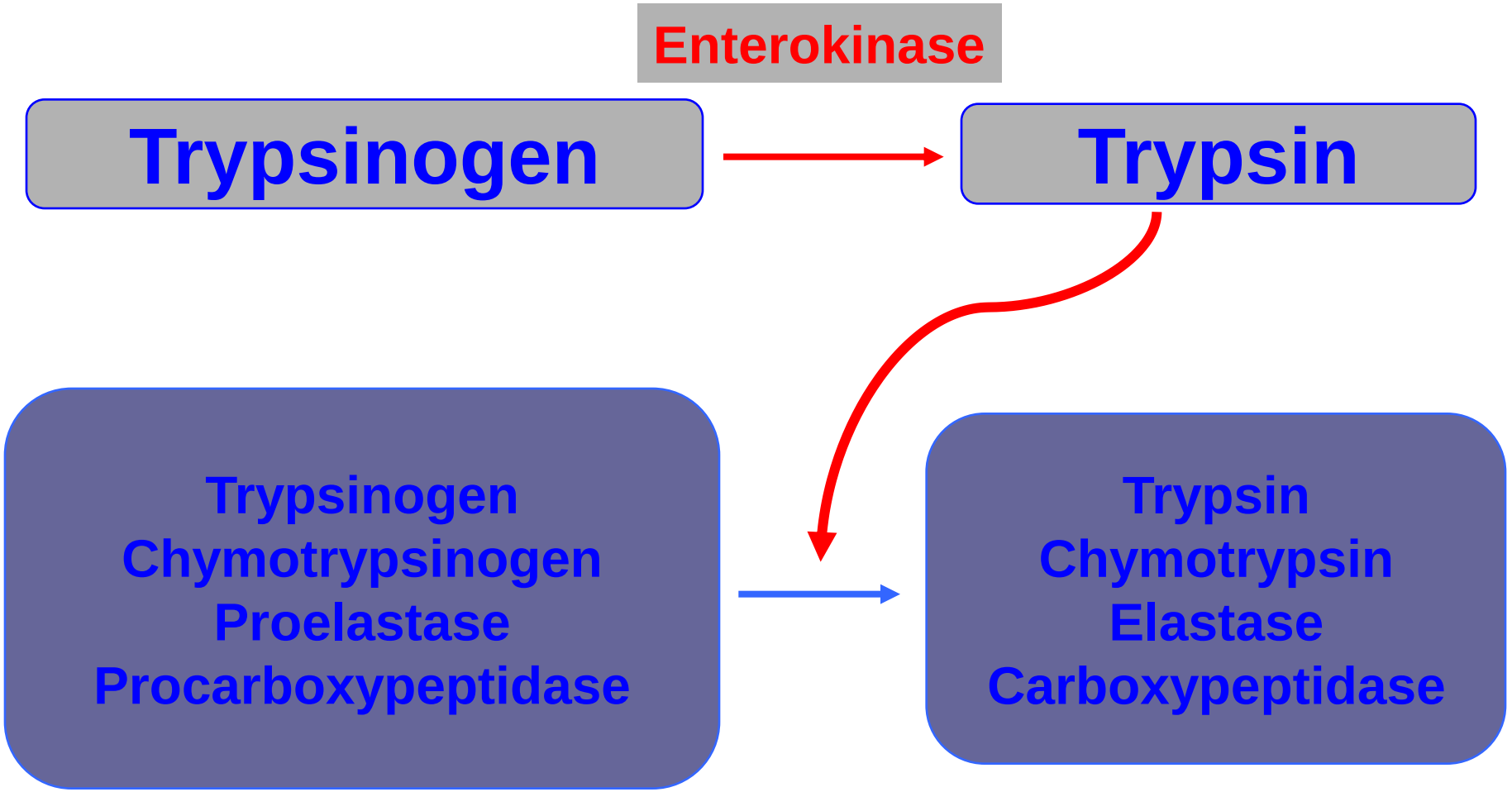
Figure 29-2 Locations of important transport processes involved in the elaboration of pancreatic juice. Acinar fluid is isotonic and resembles plasma in its concentrations of Na^+, K^+, Cl^-, and HCO_3^-. Secretion of acinar fluid and the proteins that it contains is stimulated primarily by cholecystokinin. The hormone secretin stimulates secretion of water and electrolytes from the cells that line the extralobular ducts. The secretin-stimulated secretion is richer in HCO_3^- than the acinar secretion because of Cl^-/HCO_3^- exchange. (Adapted from Swanson CH, Solomon AK: J Gen Physiol 62:407, 1973.)

(2) Alkaline secretion (Sodium Bicarbonate)

Neutralise acids from stomach

- enabling enzymes to function

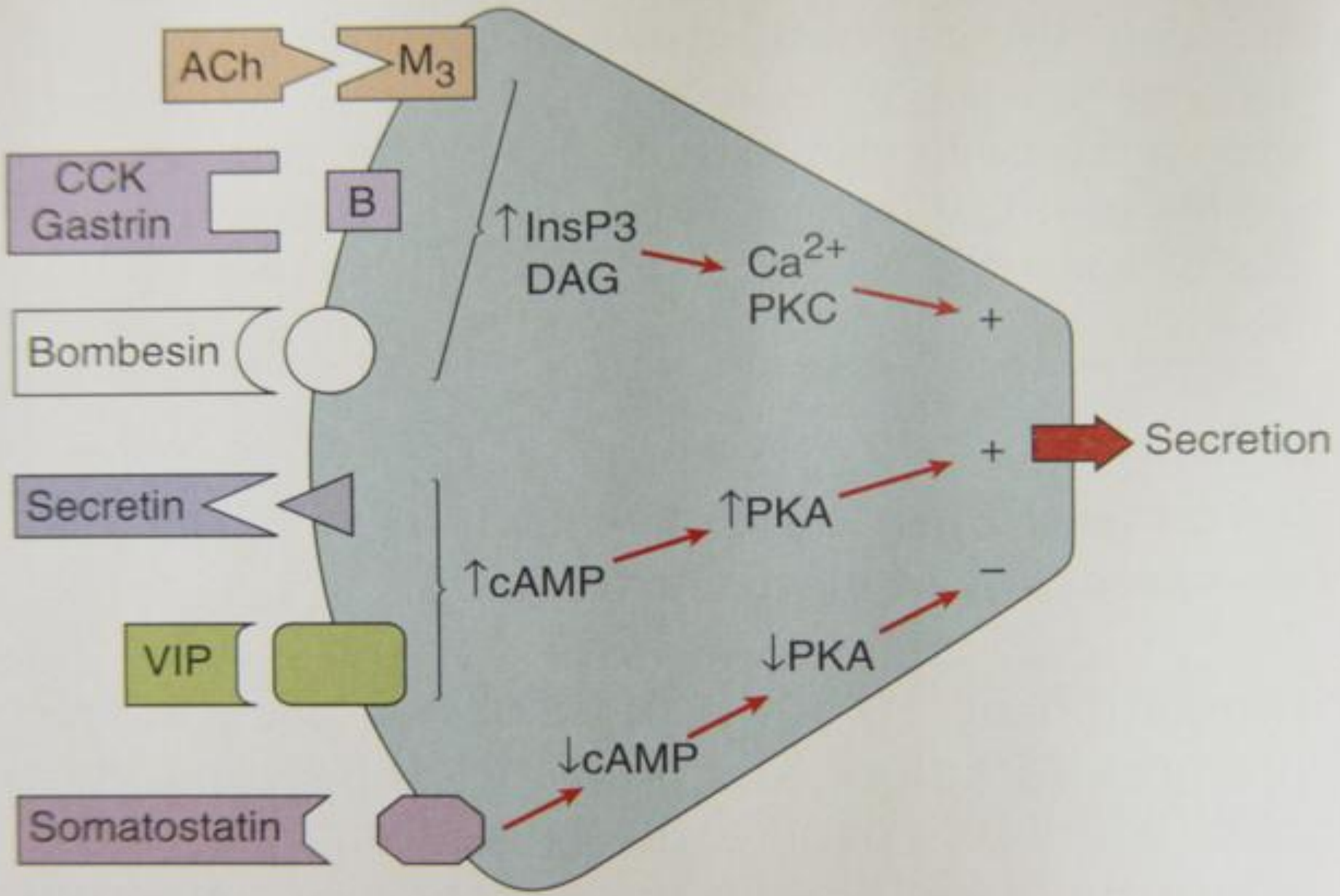
Activation of pancreatic proteases



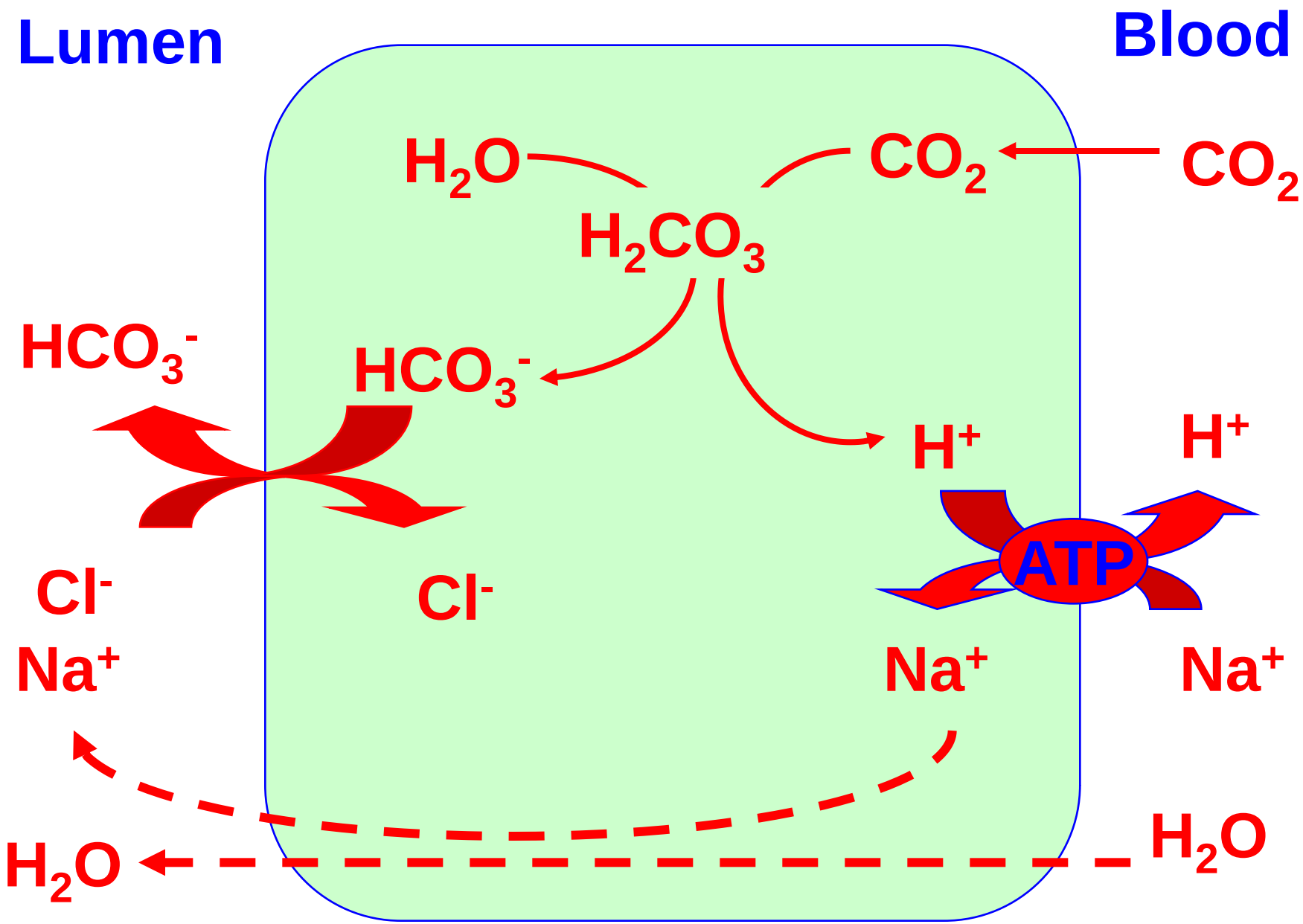
Active proteases inactivated by trypsin

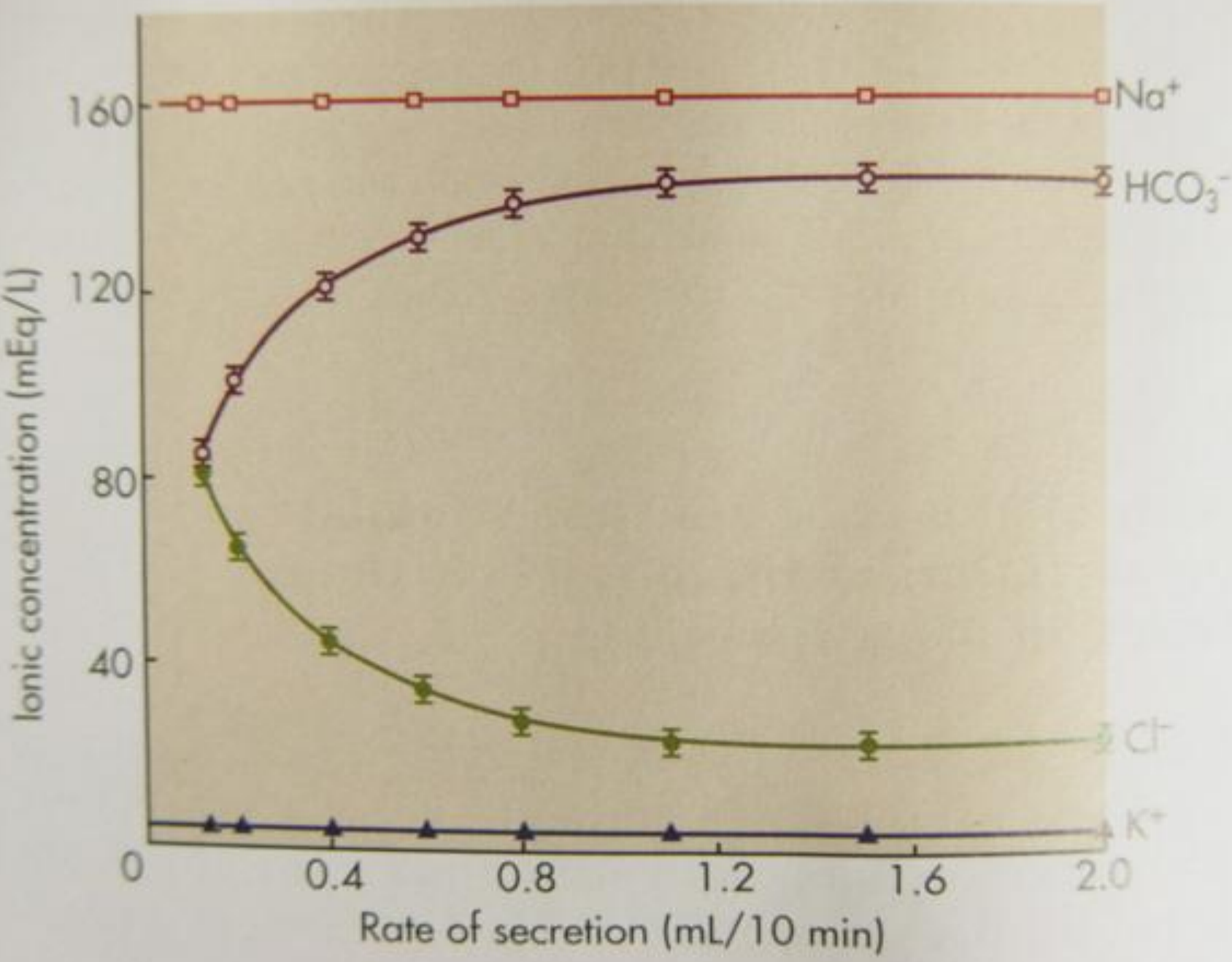
Table 29-1. Products of Pancreatic Acinar Cells

Precursors of Proteases
Trypsinogen
Chymotrypsinogen
Proelastase
Procarboxypeptidase A
Procarboxypeptidase B
Starch-Digesting Enzymes
Amylase
Lipid-Digesting Enzymes or Precursors
Lipase
Nonspecific esterase
Prophospholipase A_2
Nucleases
Deoxyribonuclease
Ribonuclease
Regulatory Factors
Procolipase
Trypsin inhibitors
Monitor peptide


ACh
M_3
CCK
Gastrin
B
Bombesin
↑InsP3
DAG
Ca^{2+}
PKC
+
Secretion
Secretin
↑PKA
+
↑cAMP
–
VIP
↓PKA
↓cAMP
Somatostatin

Bicarbonate secretion




160
120
80
40
0
Ionic concentration (mEq/L)
Na+
HCO3−
Cl−
K+
0.4
0.8
1.2
1.6
2.0
Rate of secretion (mL/10 min)

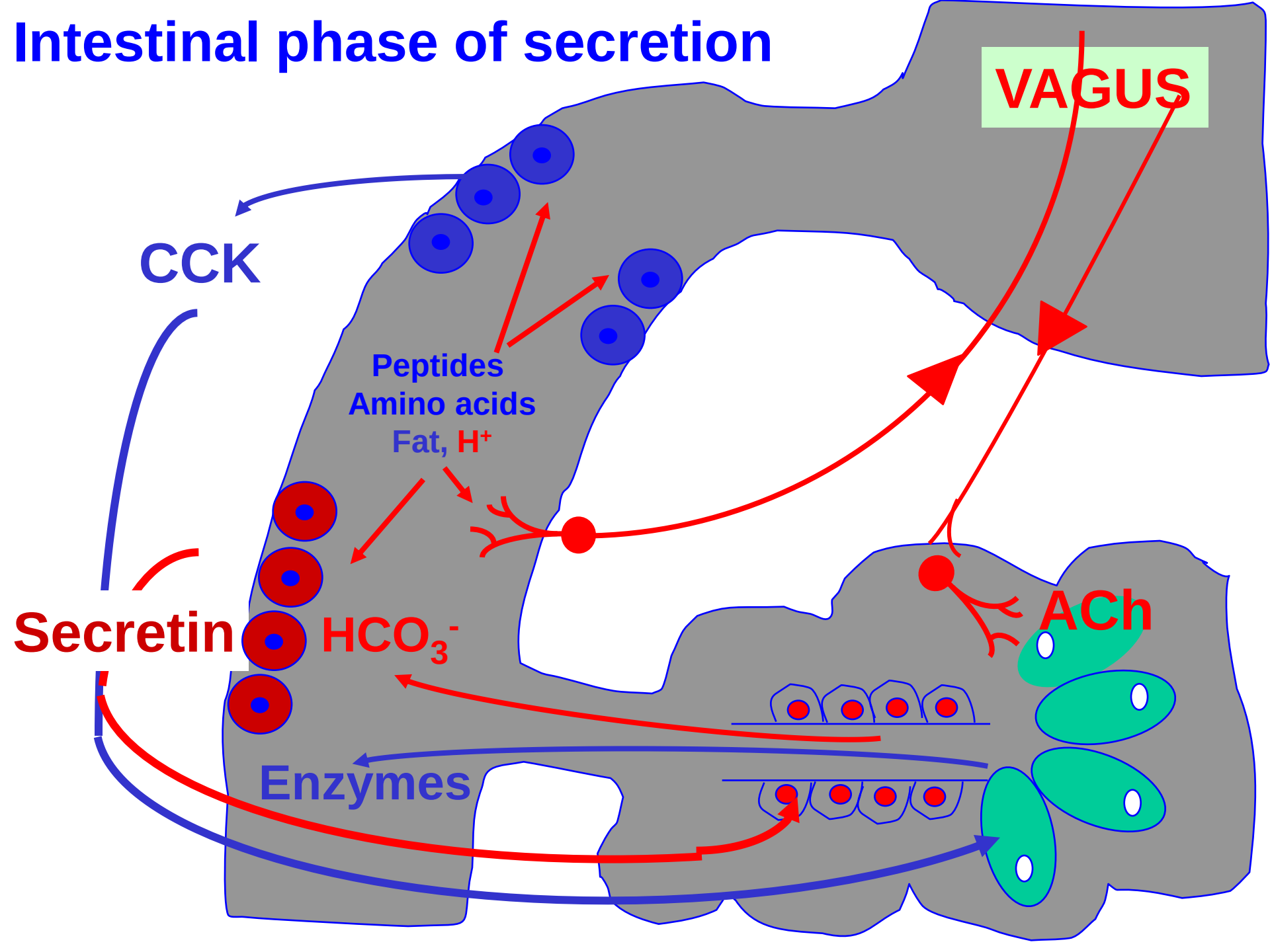
Regulation of secretion

- Neural (Parasympa ↑ & sympa ↓
- Hormonal Secretin (aqueous) & CCK (enzyme)

Pahses

- Cephalic 25%
- Gastric 10%
- Intestinal 65%

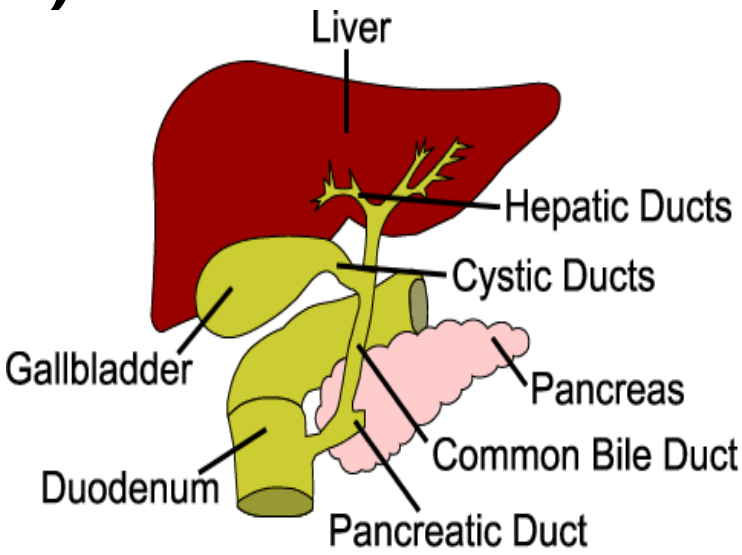
Intestinal phase of secretion



Liver (Bile)

Liver produces bile salts & gallbladder

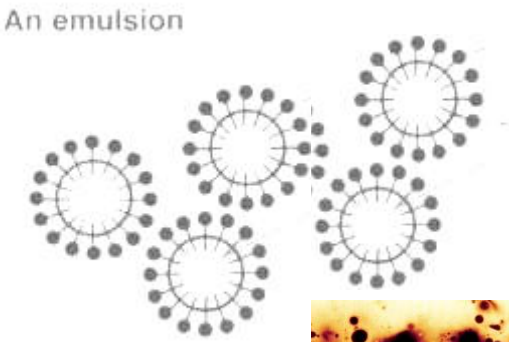
stores & concentrates it



Bile

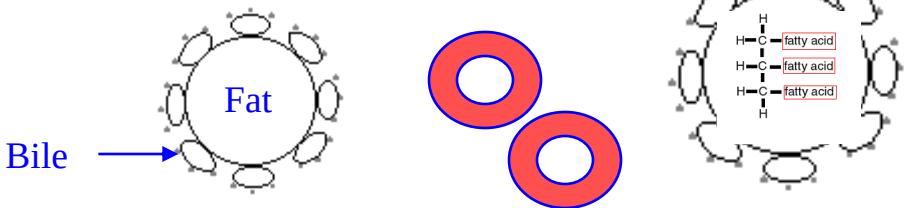
(A) Converts large fat globule into an

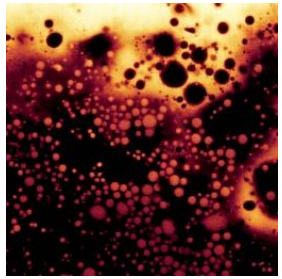
emulsion of fat droplets - greater area



(B) Transport of fat droplets -

fat is difficult to transport





Microscopic Anatomy of the Liver

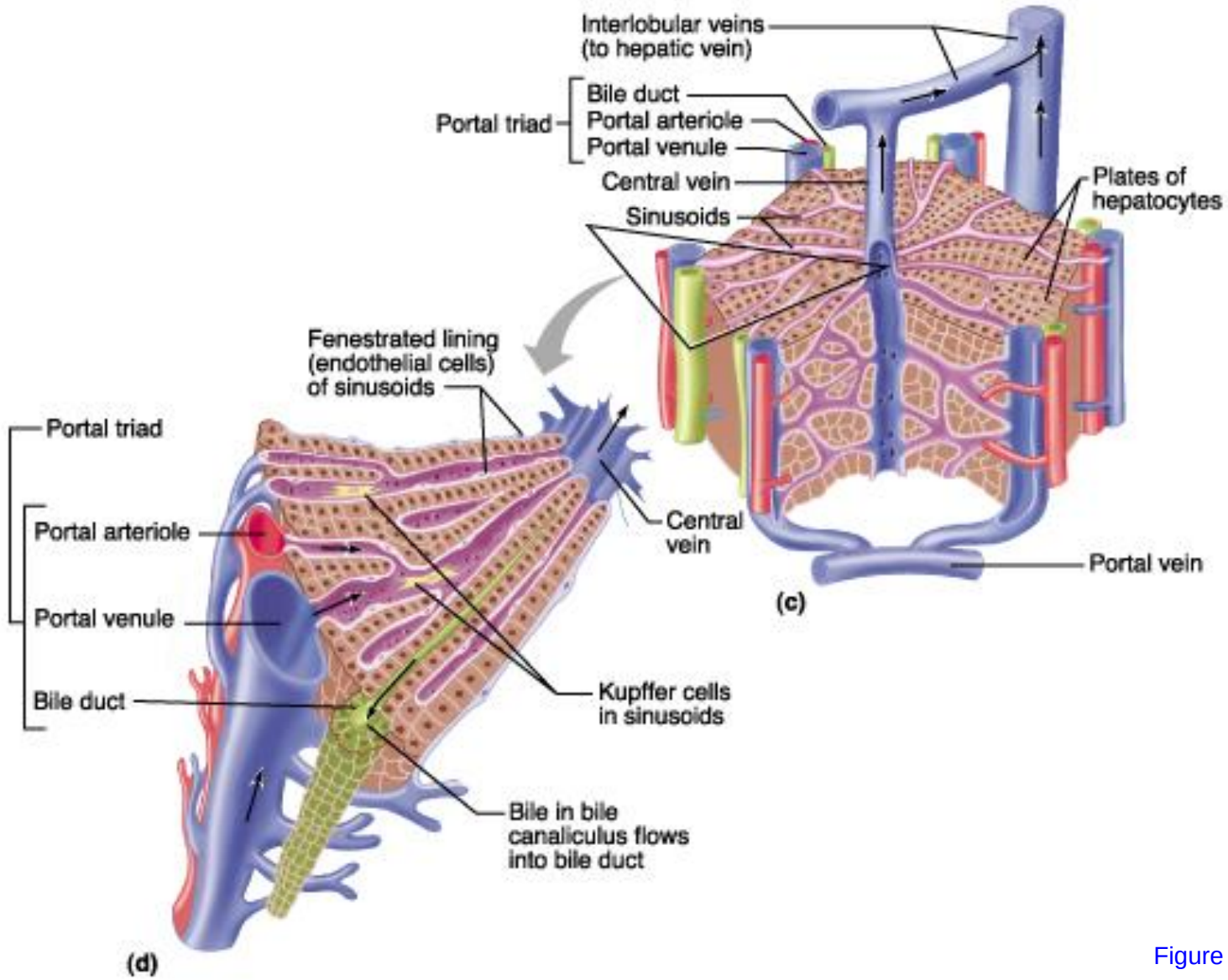
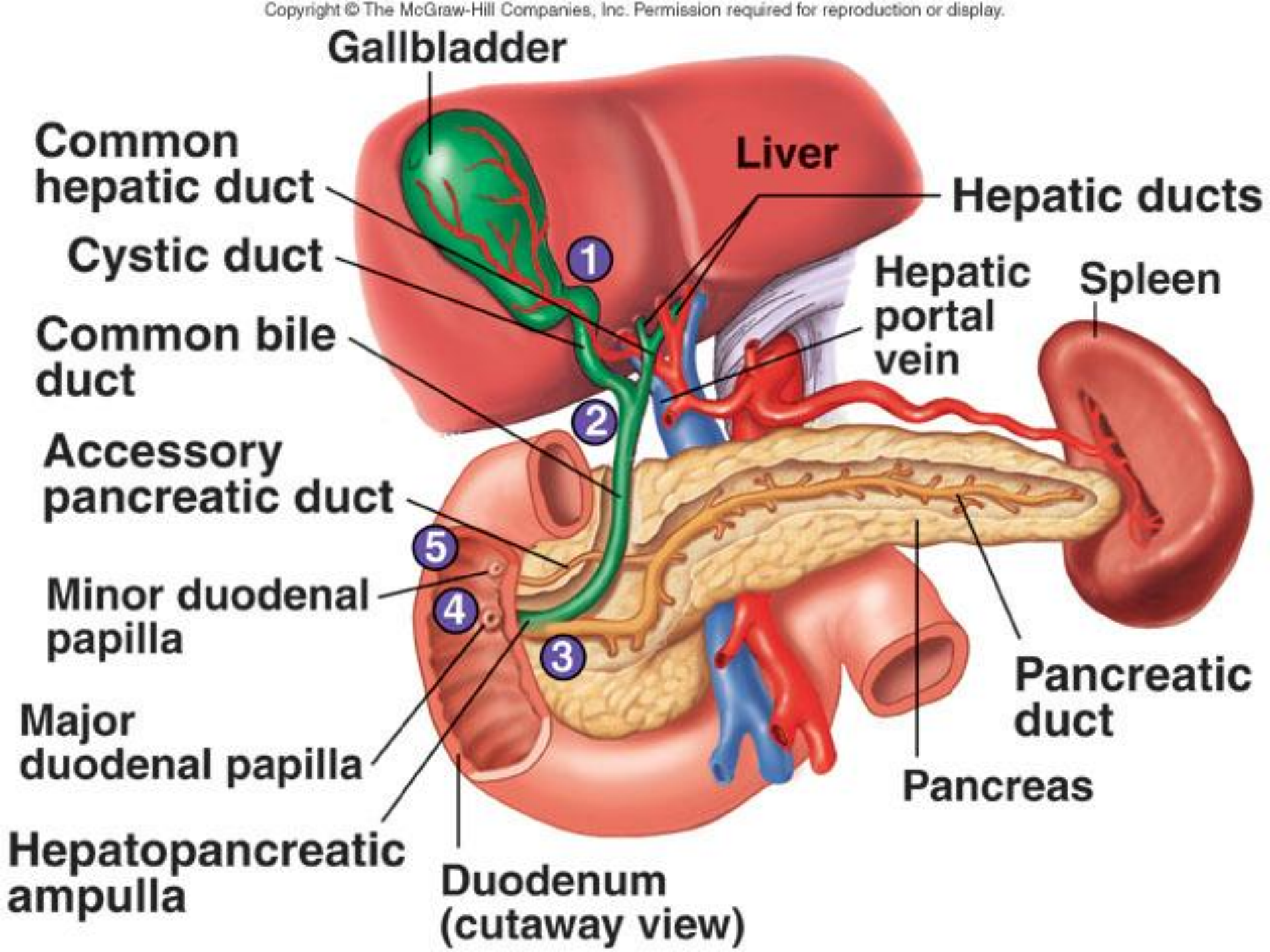
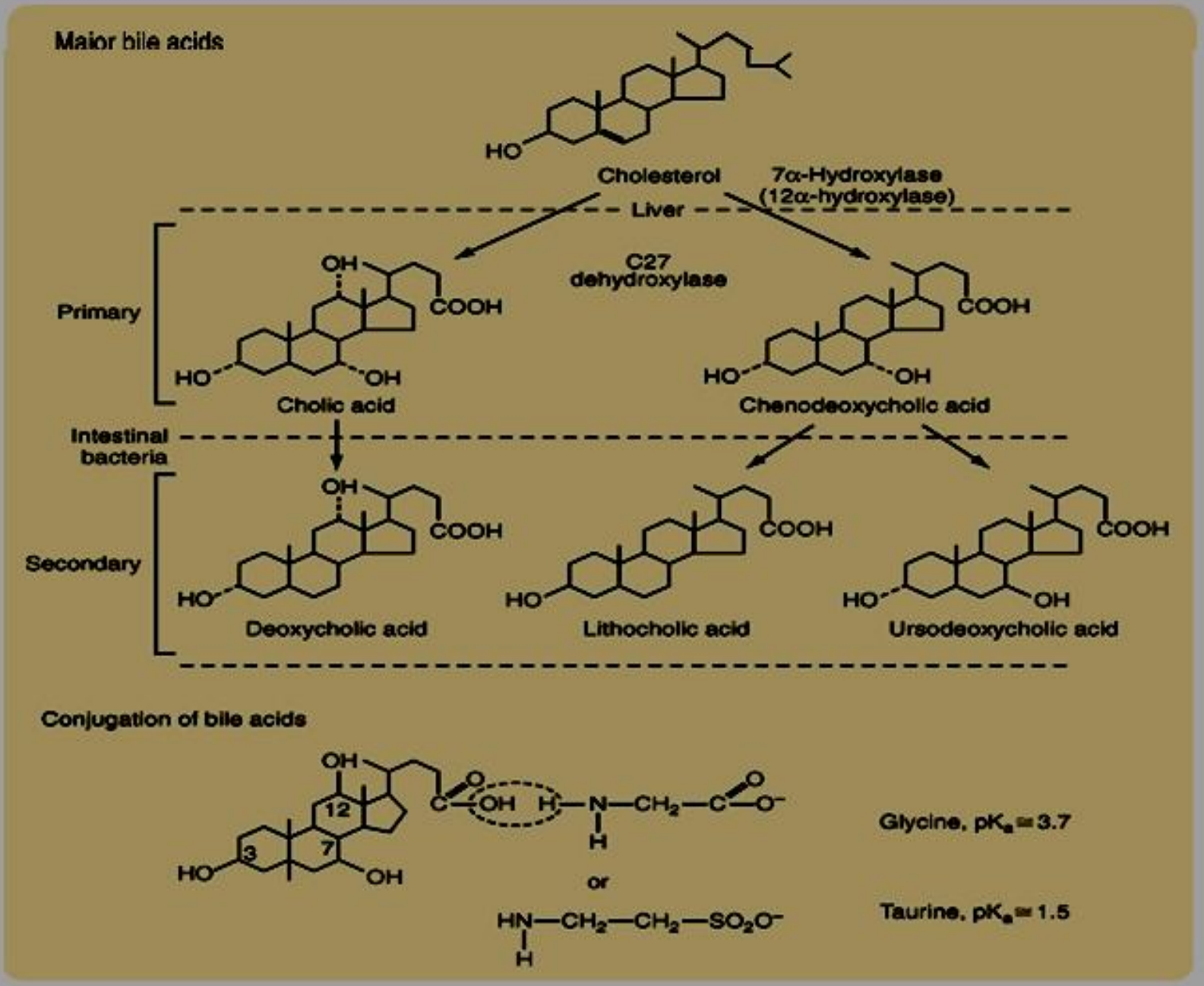


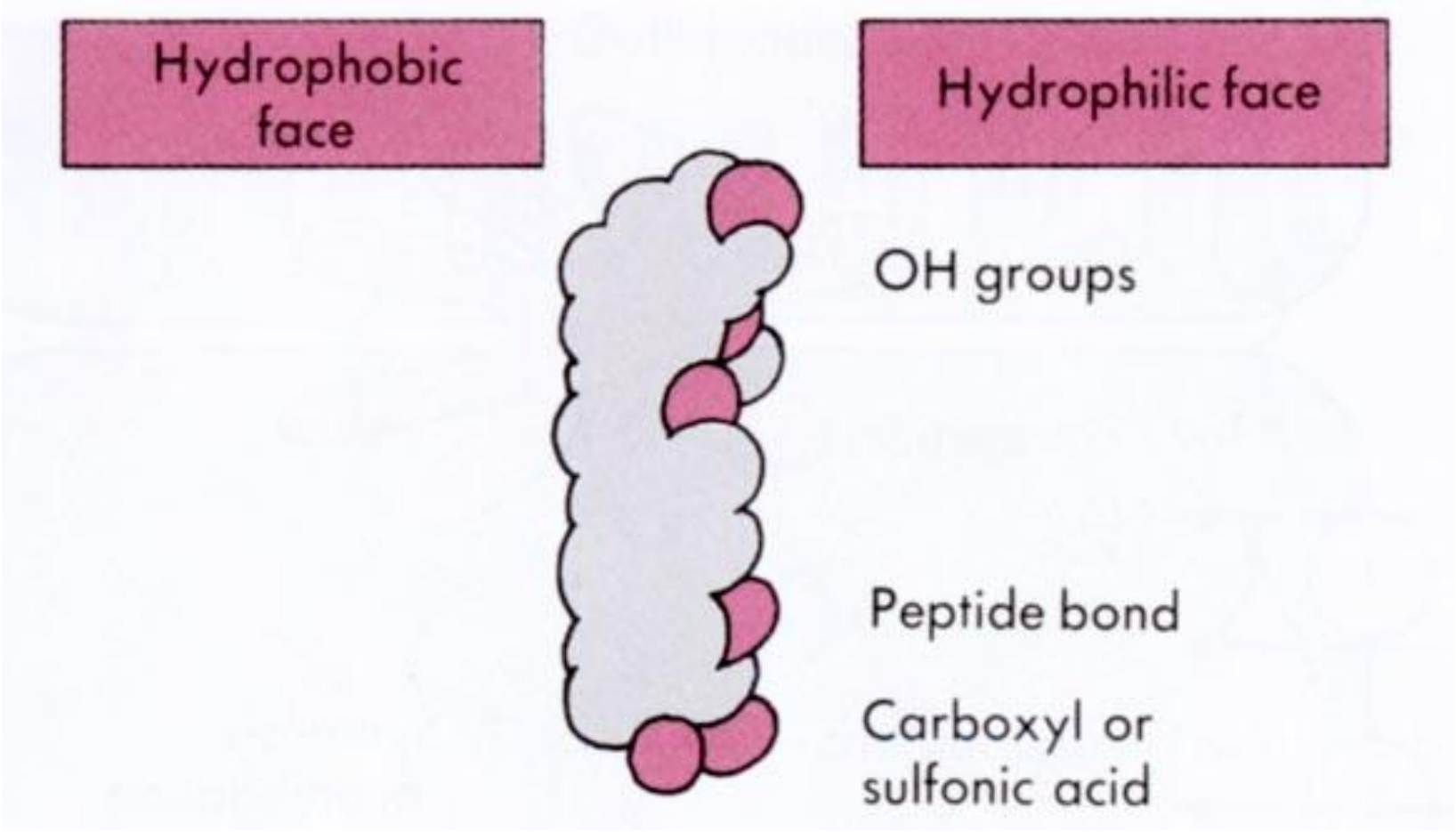
Figure 24.24c, d



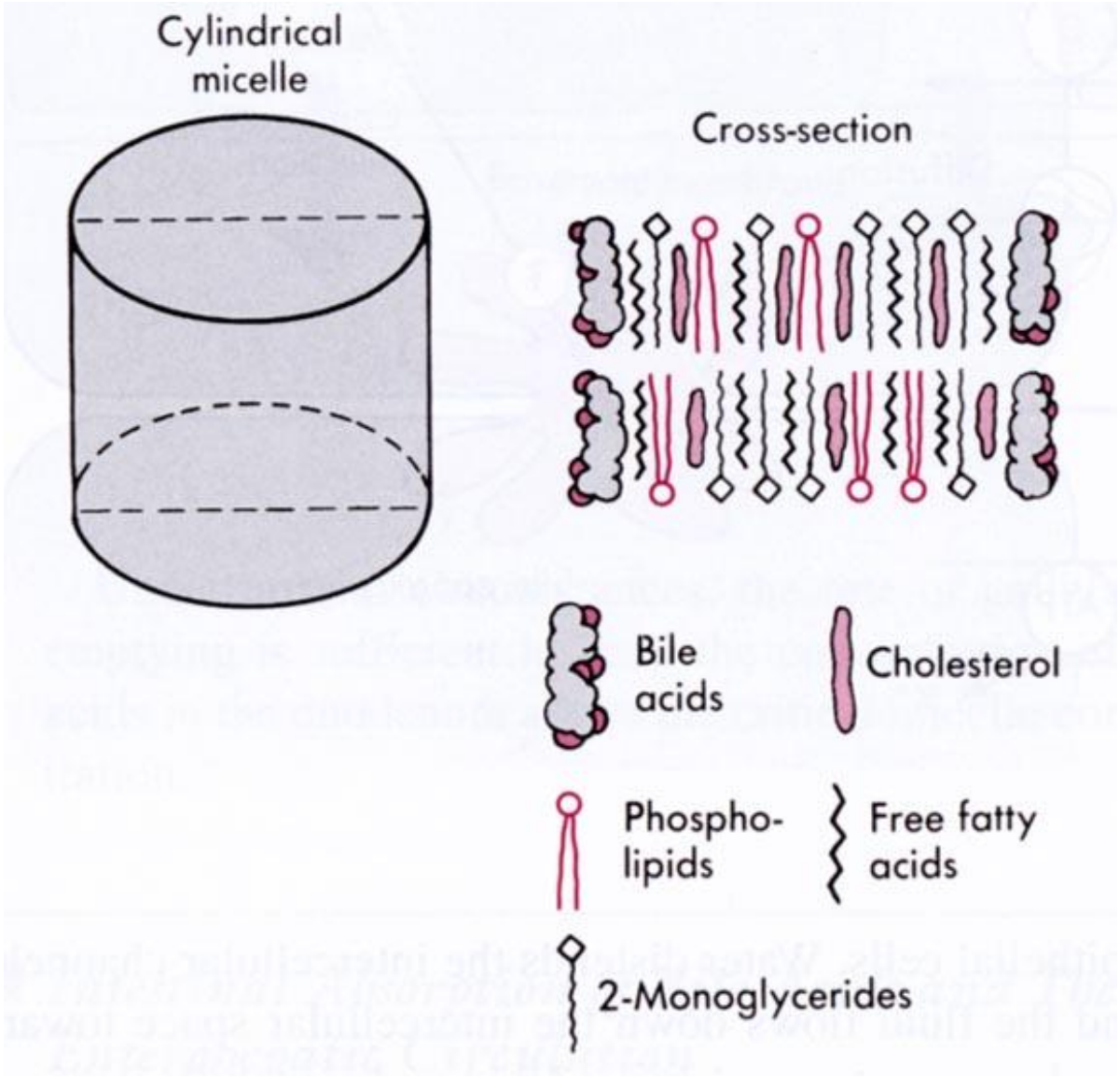
Bile Acid Synthesis



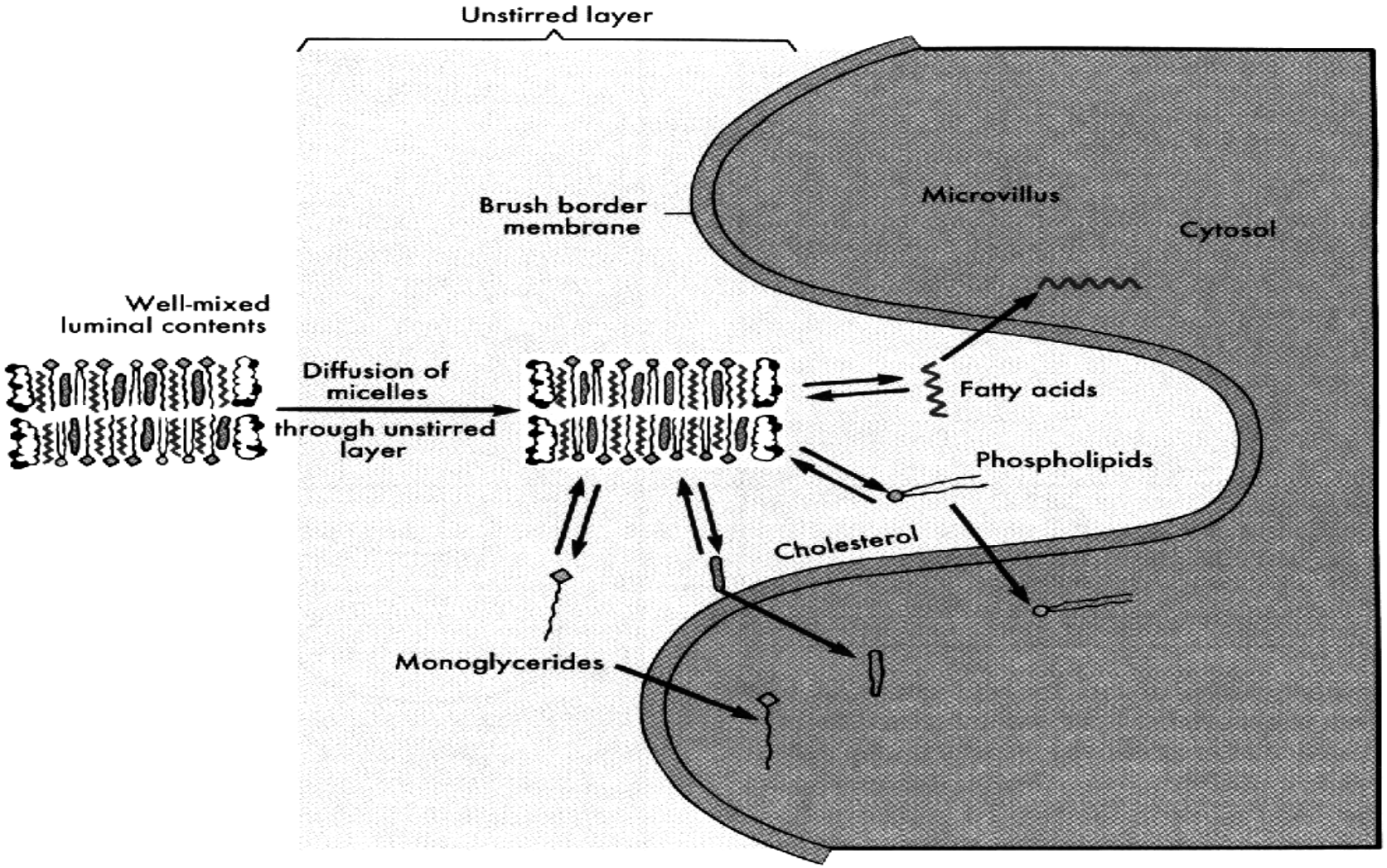
Cartoon of a Bile Acid

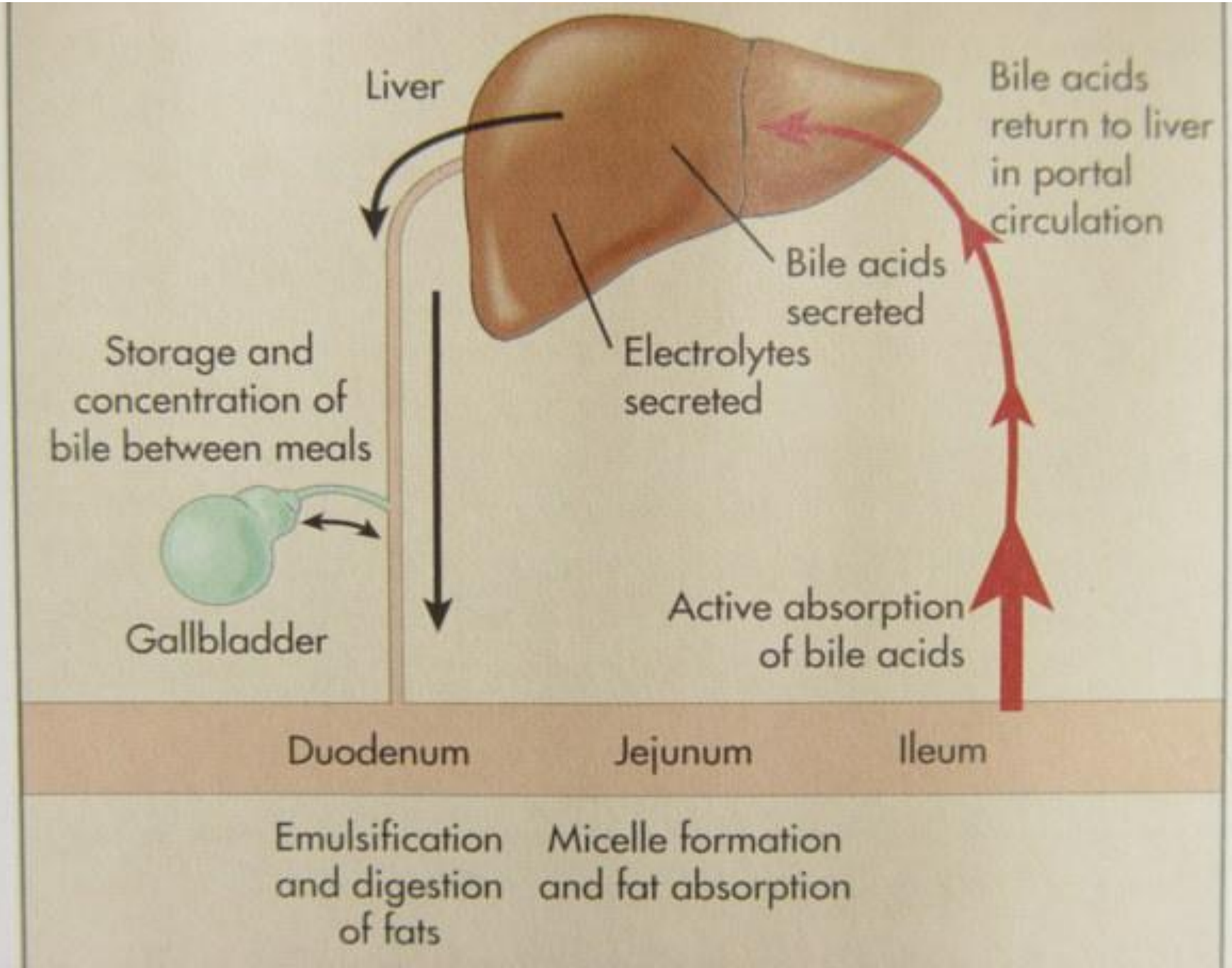


Form micelle



Helps lipid absorption




Liver
Bile acids return to liver in portal circulation
Bile acids secreted
Electrolytes secreted
Storage and concentration of bile between meals
Gallbladder
Active absorption of bile acids
Duodenum
Jejunum
Ileum
Emulsification and digestion of fats
Micelle formation and fat absorption

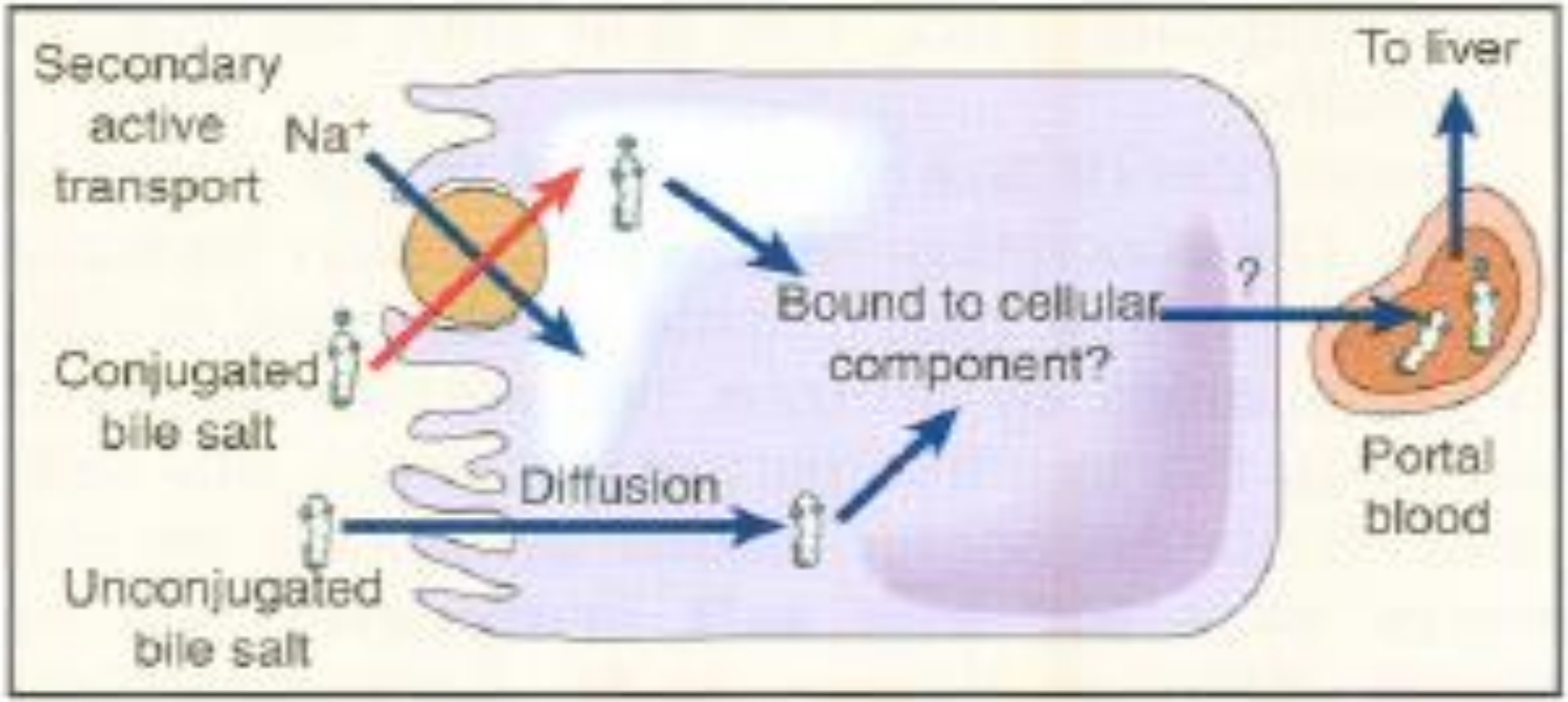


FIGURE 35–8. Absorption of bile salts by epithelial cells of the terminal ileum. Bile salts are absorbed both by simple diffusion and by Na^+–bile salt symporter. Conjugated bile salts are absorbed mainly by this symporter; unconjugated bile salts are absorbed chiefly by diffusion.

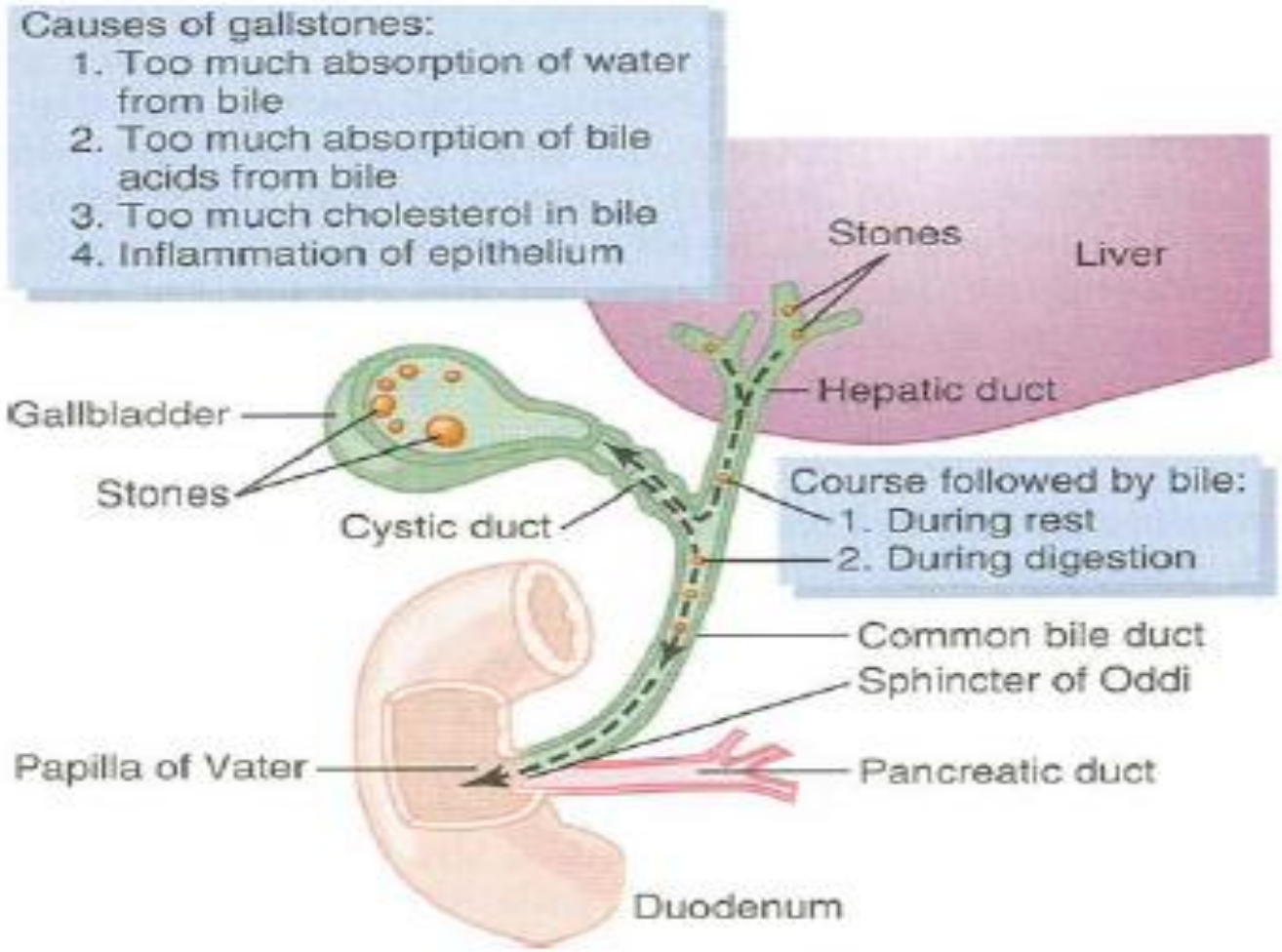
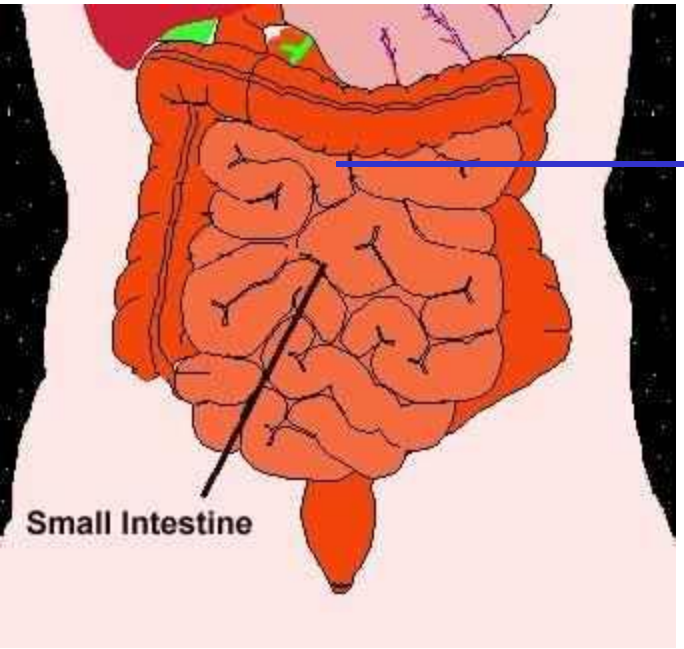


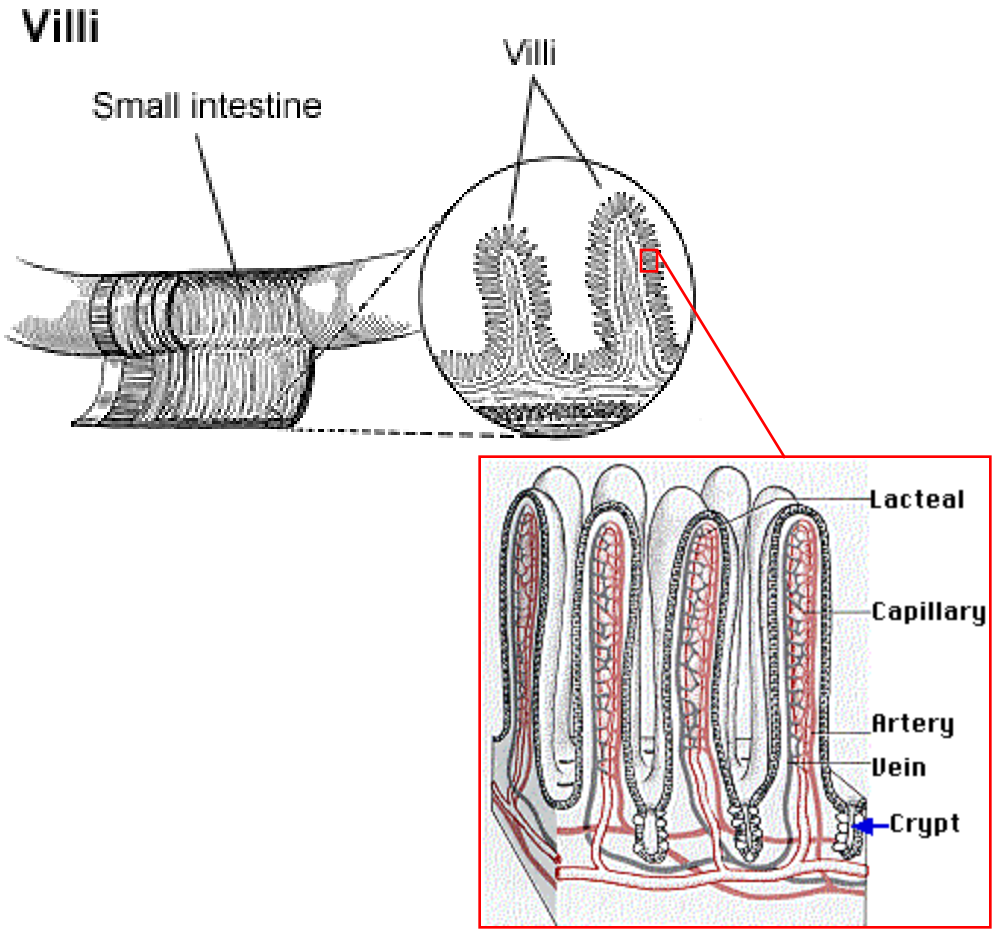
Figure 64–12

Formation of gallstones.

Small Intestine

Site at which most digestion and absorption takes place, no further digestion or absorption of nutrients occurs from here





Intestinal secretion

Duodenum

- Bruner's gland ⟶ HCO3 & Mucus
- Stimulated by parasympathetic & mechanical & secretin
- Sympathetic stimulation ⟶ decreases

Crypt of lieberkuhn

- Secretes Na & Cl & water
- Stimulated by:

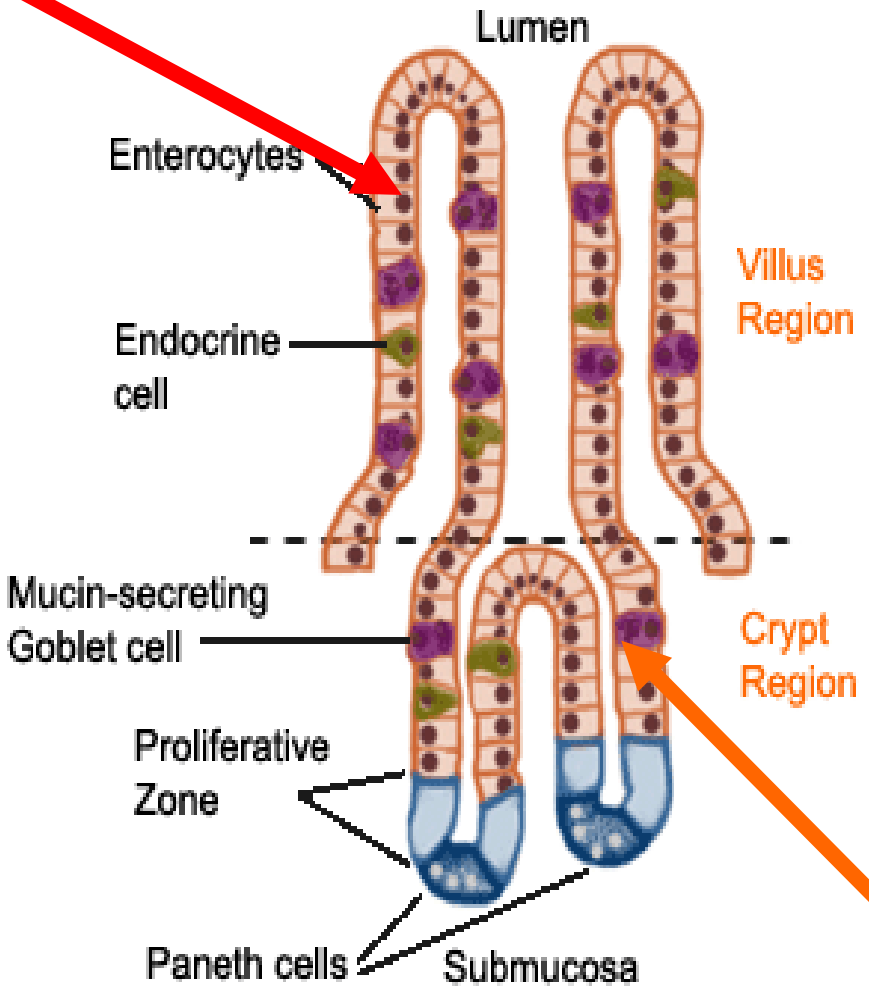
Local reflexes & mechanical stimuli

Goblet cells:

- Mucus

a) COMPLETE DIGESTION

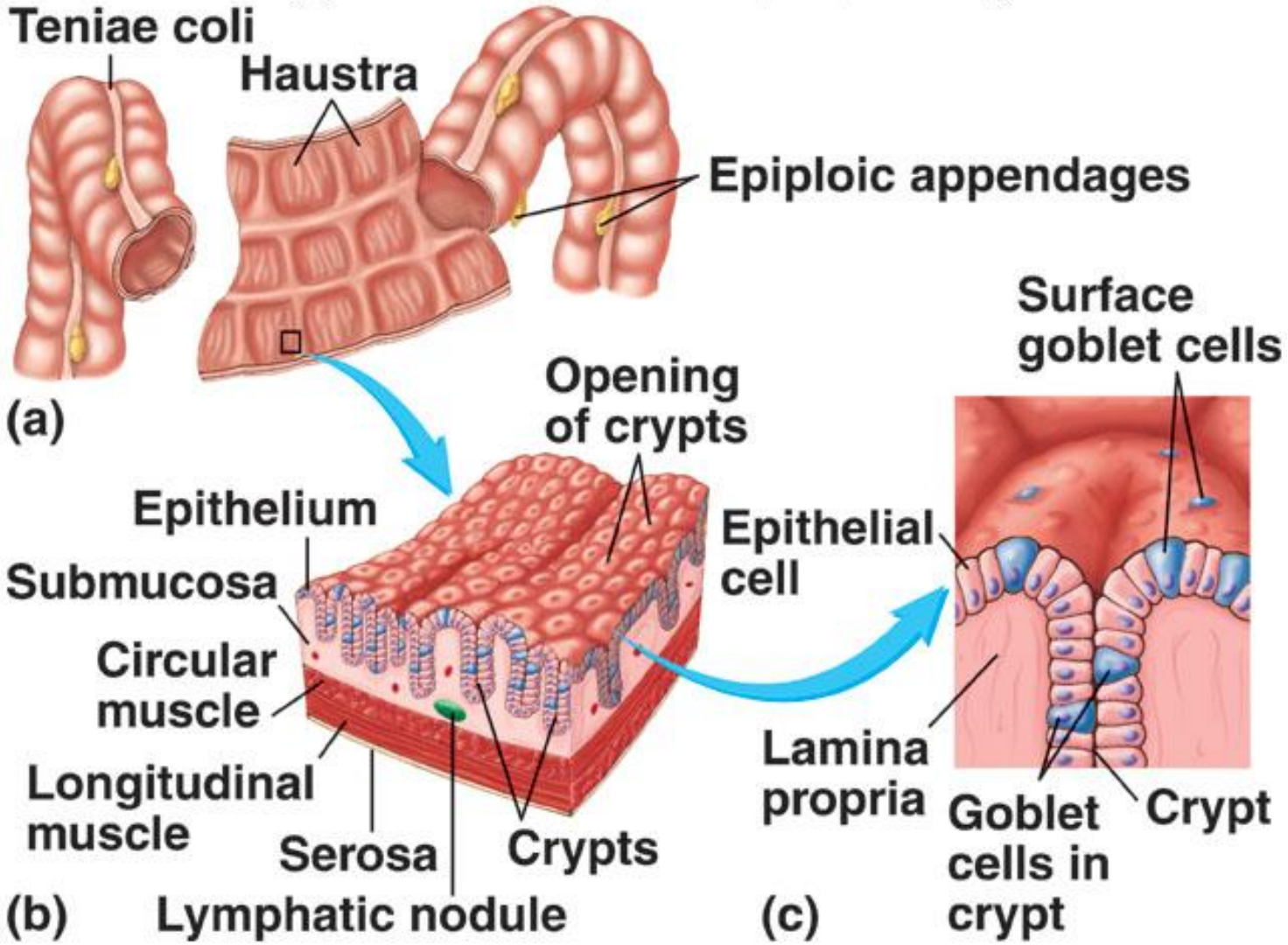
b) ABSORPTION



Absorption and Secretion occur simultaneously

FLUID SECRETION

Histology of Large Intestine



Colonic sercretion

- Low volume
- High mucus by goblet cells
- Aqueous ⟶ Rich of K & Bicarbonate
- Stimulated by mechanical & cholinergic
- Sympathetic stimulation ⟶ Decrease secretion

Large Intestine

Stores and concentrates faecal material before defecation

Secretion of mucous for protection of mucosa

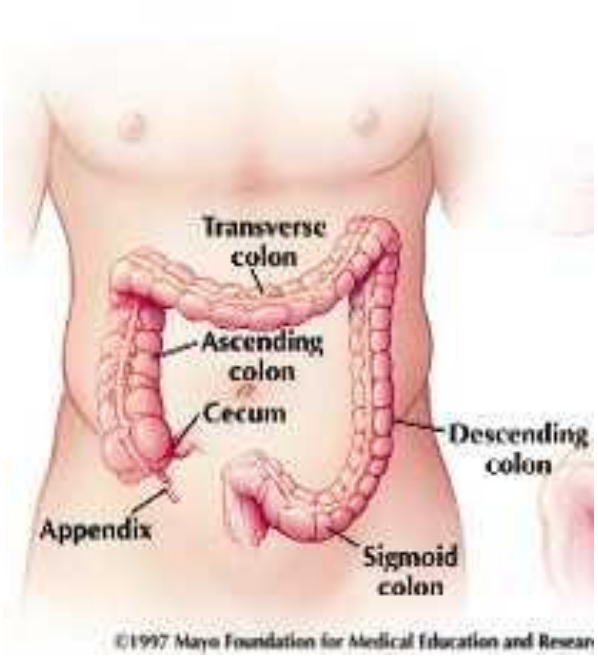
No nutrient absorption,

only salts and relatively

small amounts of water

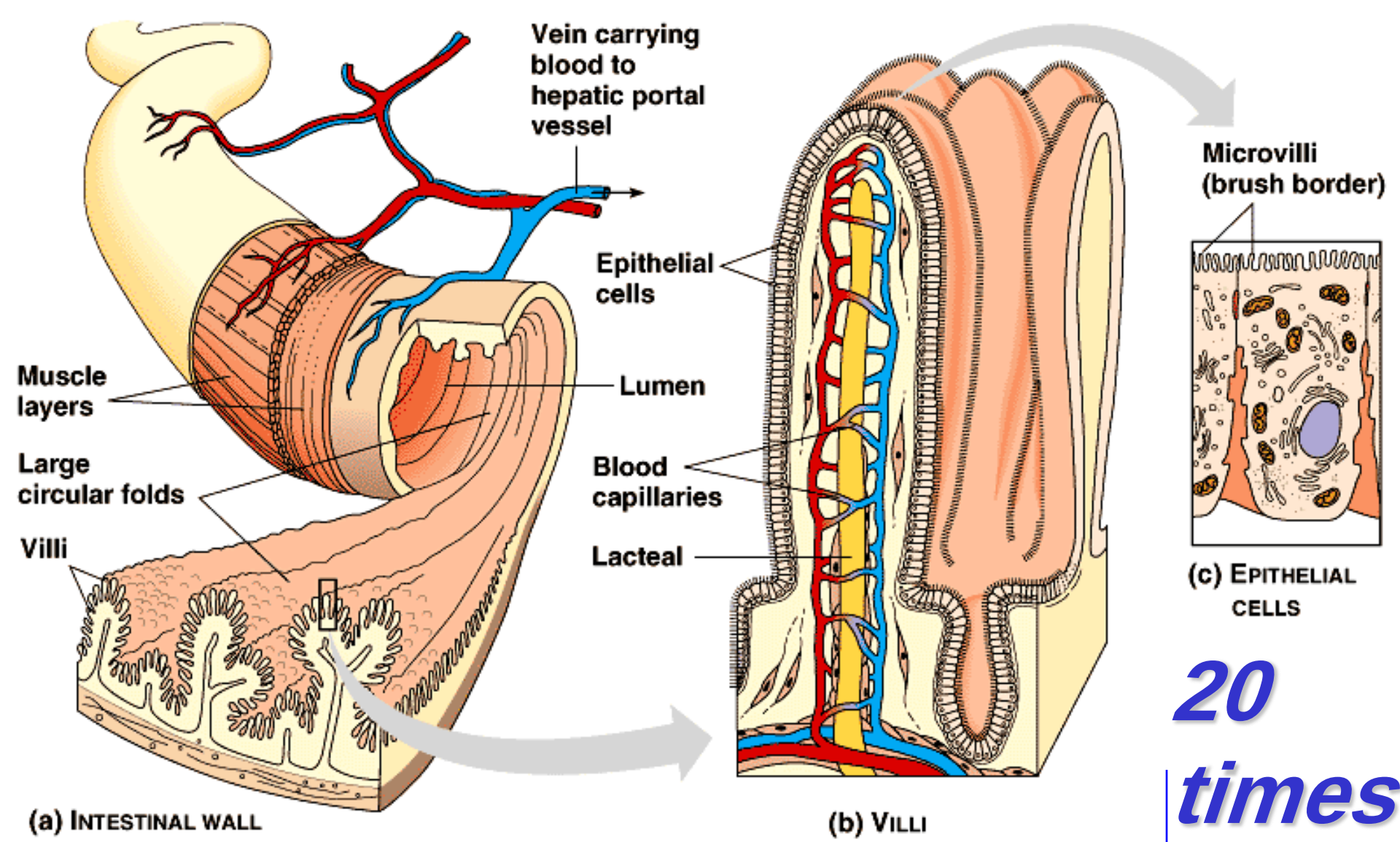
Faeces: Water, unabsorbed

food e.g. cellulose, bacteria



Small Intestine

- Mixing and segmentation of contents - no secretion
    - Brings contents in contact with epithelial surface
- Digestion in the lumen is accomplished by secretions from the pancreas
- Digestion occurs within the epithelial cells of the intestine
- Minerals are also absorbed



20 times

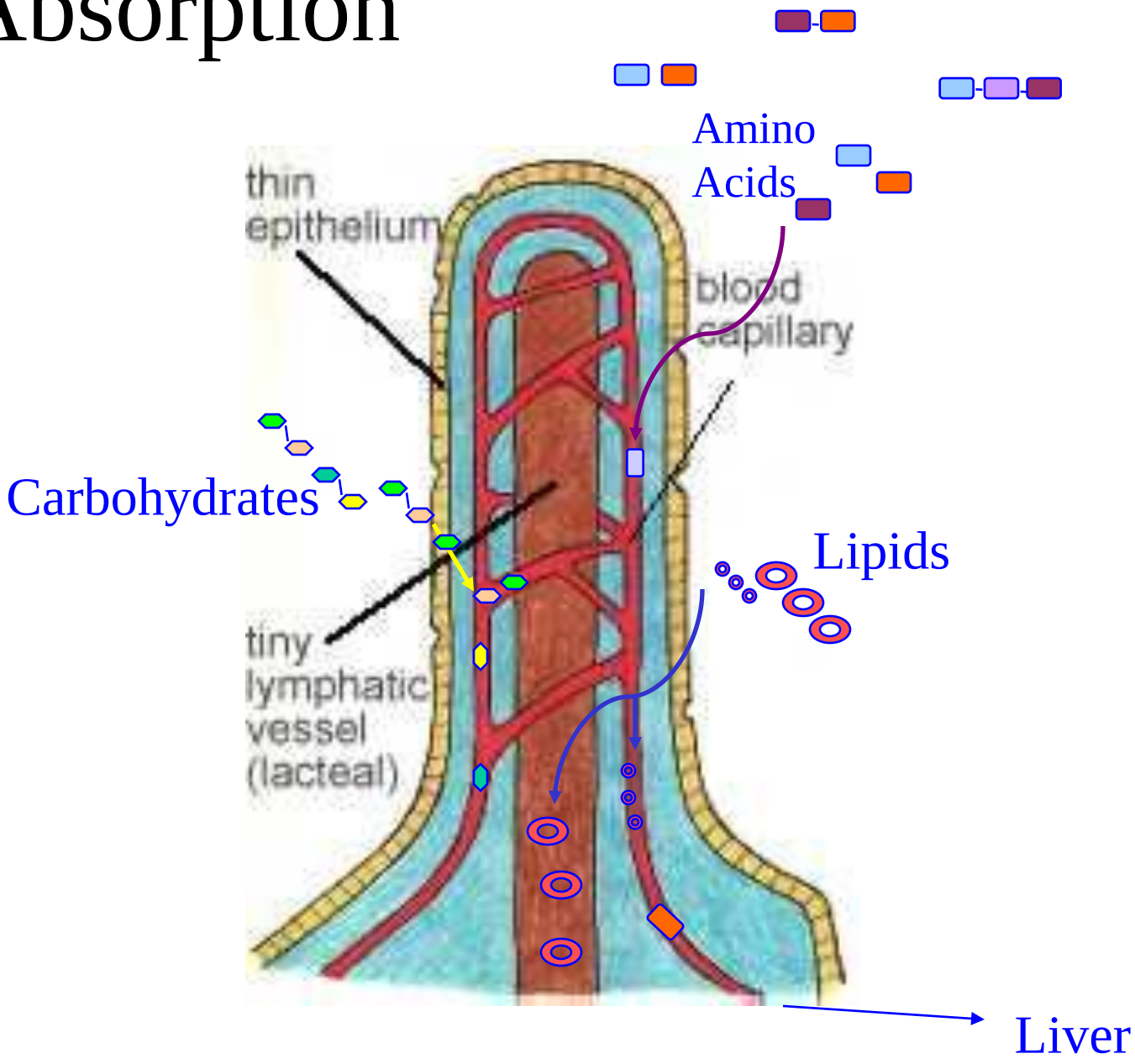
10 times

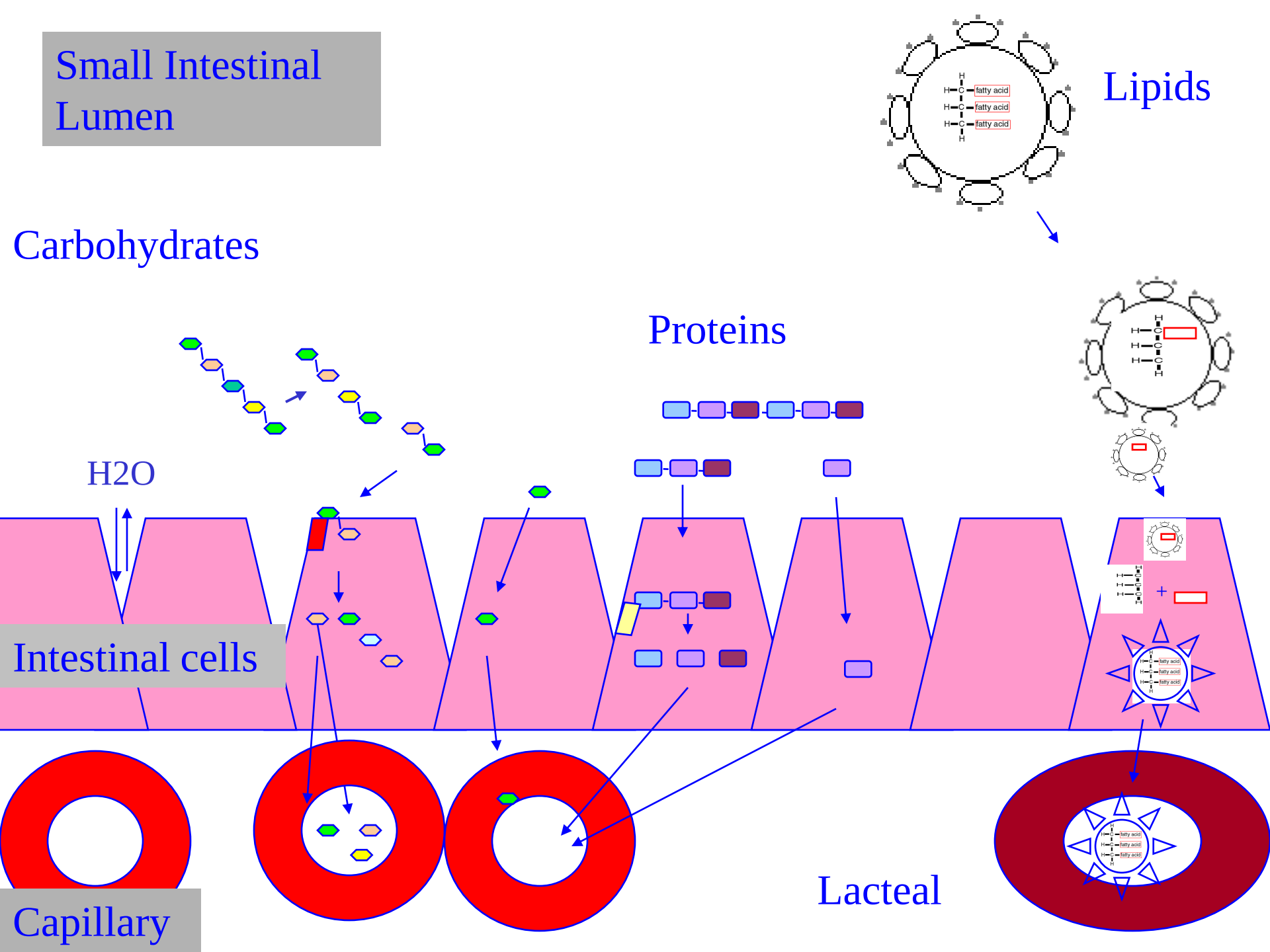
3 times

600 times

Ouzr istaiiram

Absorption

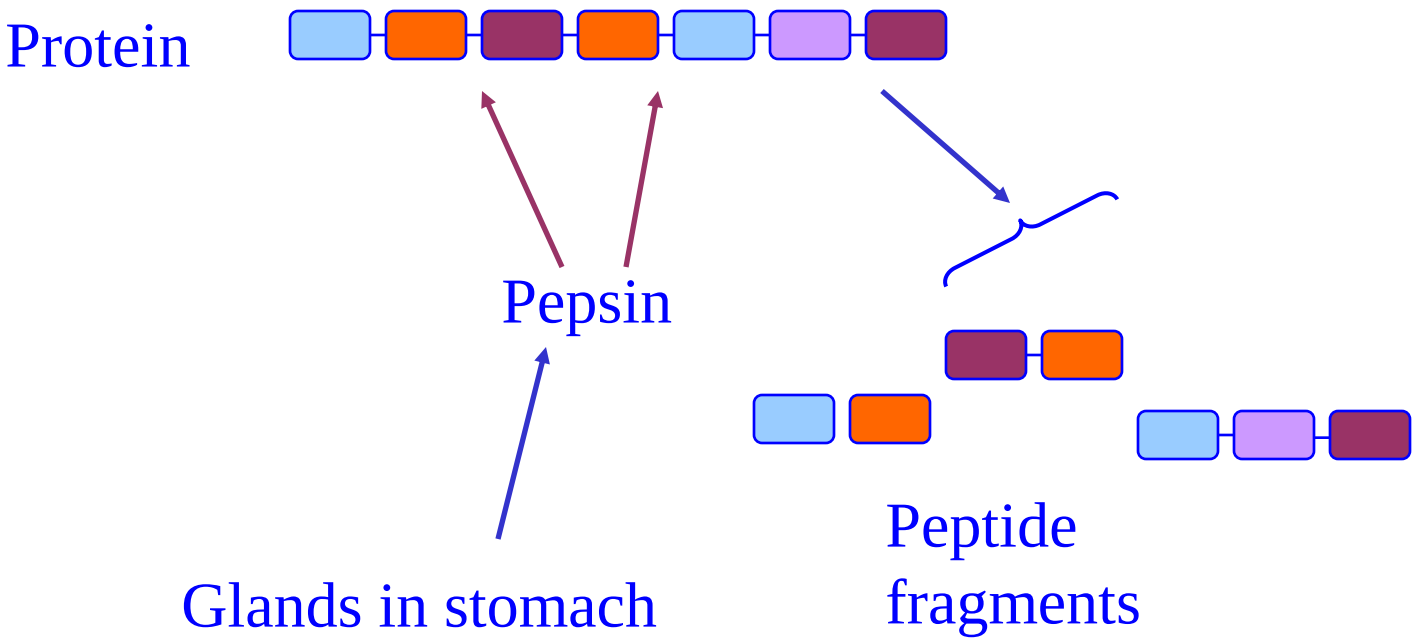

Amino
Acids
thin
epithelium
blood
capillary
Carbohydrates
Lipids
tiny
lymphatic
vessel
(lacteal)
Liver


Small Intestinal Lumen
Lipids
Carbohydrates
Proteins
H2O
Intestinal cells
Capillary
Lacteal

Enzymes

- Biological catalysts which greatly increase the rate of a chemical reaction but are not themselves changed during the process
- Enzymes are central to the digestion process.

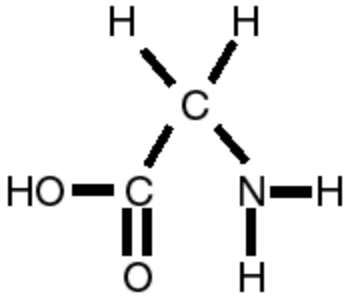
Digestion

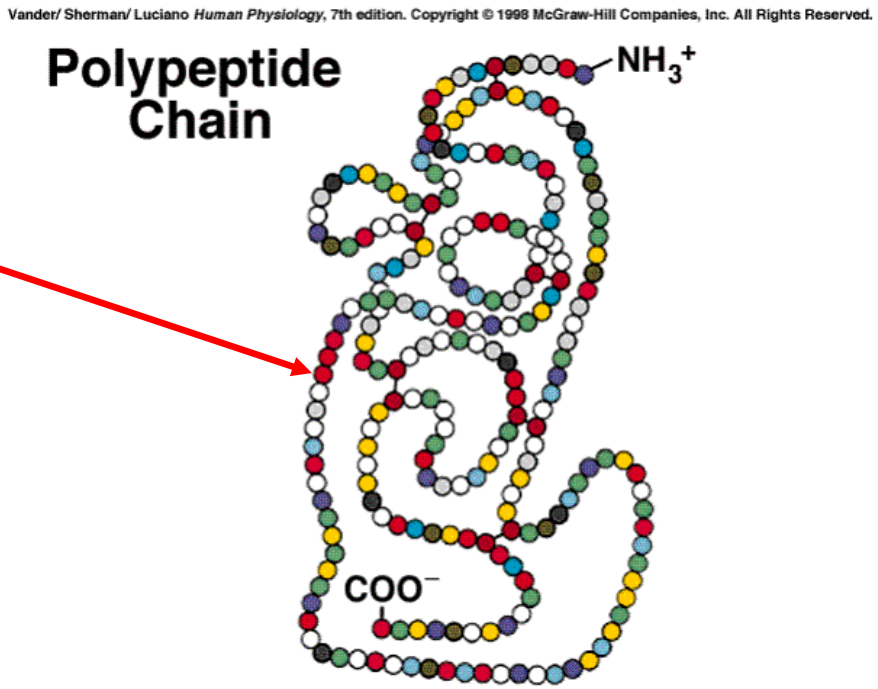


Proteins

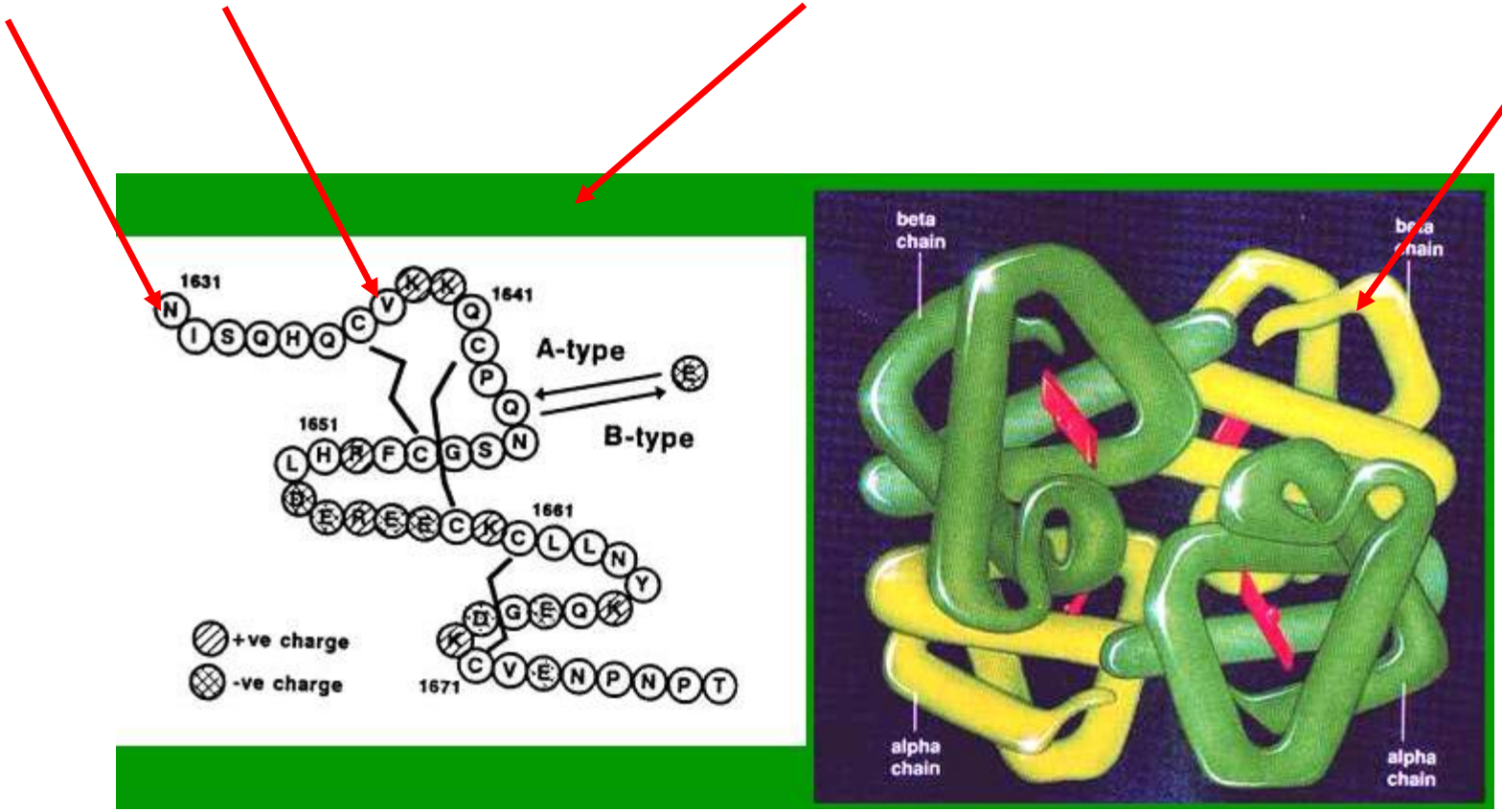
Structure

Amino Acids - glycine





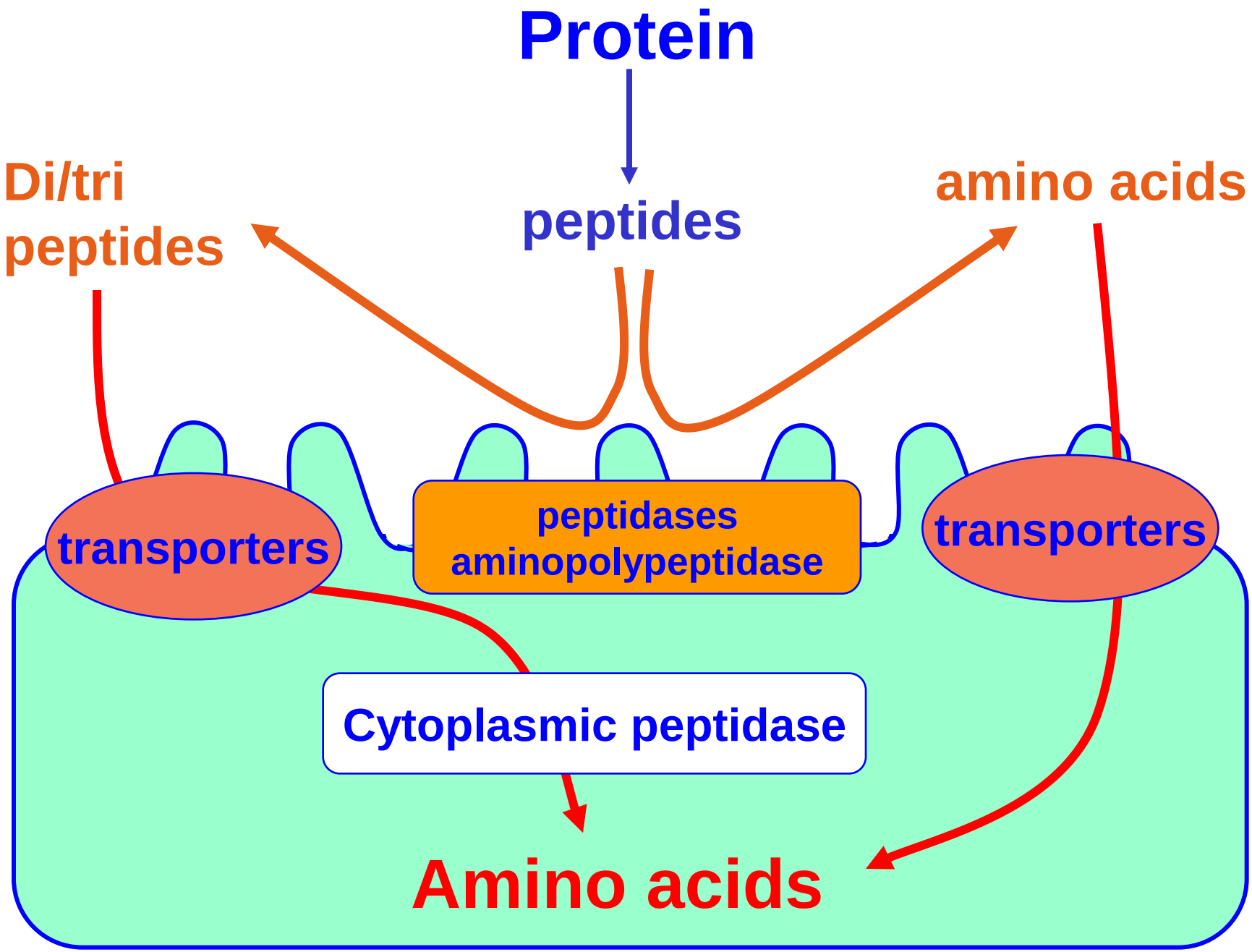
Amino acids combine to form peptides which combine to form proteins



Protein digestion & absorption

Protein digestion involves the enzymatic degradation of proteins to di-, or tri- peptides & finally amino acids.

- Digestion begins in the stomach with the interaction with pepsin
- Further proteolytic cleavage occurs in the intestinal lumen by pancreatic trypsin, chymotrypsin, and carboxy peptidases.
- Final degradation occurs on the membrane of the intestinal microvilli by the action of aminopeptidases.
- Protein absorption occurs through active transport.


Protein
peptides
Di/tri peptides
amino acids
transporters
peptidases aminopolypeptidase
transporters
Cytoplasmic peptidase
Amino acids

The result of pancreatic and brush border enzyme

- AA & small peptides (mostly di & tri)
- They are entered into the cells
- In the cell peptides are digested
- Finally entered into blood as AA and a few as dipeptide

3 sites for digestion of protein

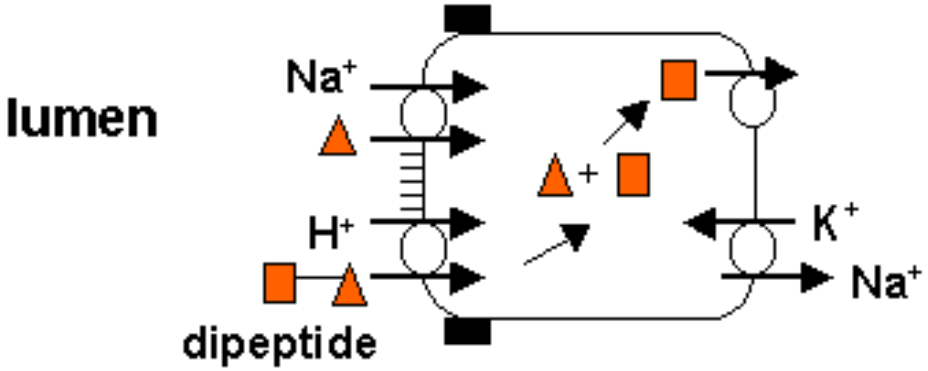
How AA are entered into the cells

- Some by Na (co-transport) (5 types)
- Some facilitated (2 types)
- Some diffusion

How Di & Tri peptides are entered into the cells

- Co-transport by Na

Co transport by H

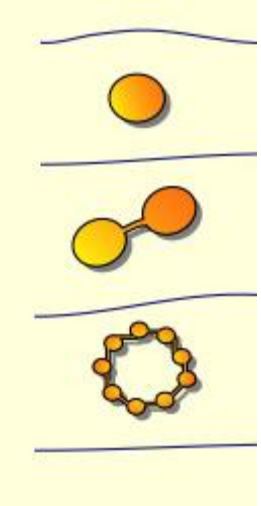


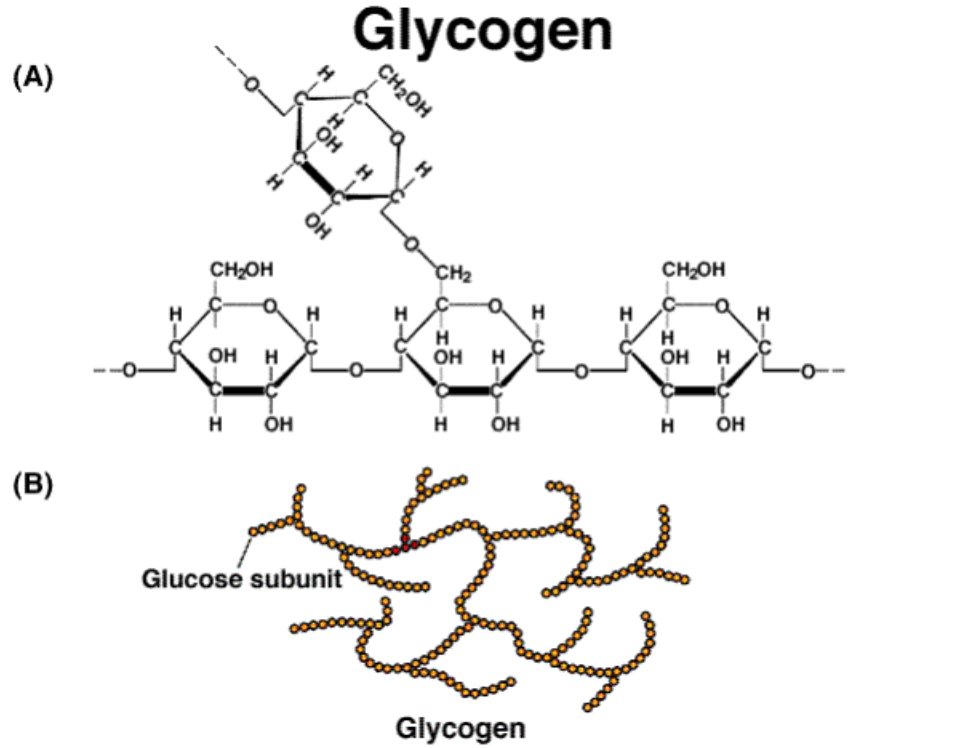
Carbohydrates

Monosaccharides

Disaccharides

Polysaccharides

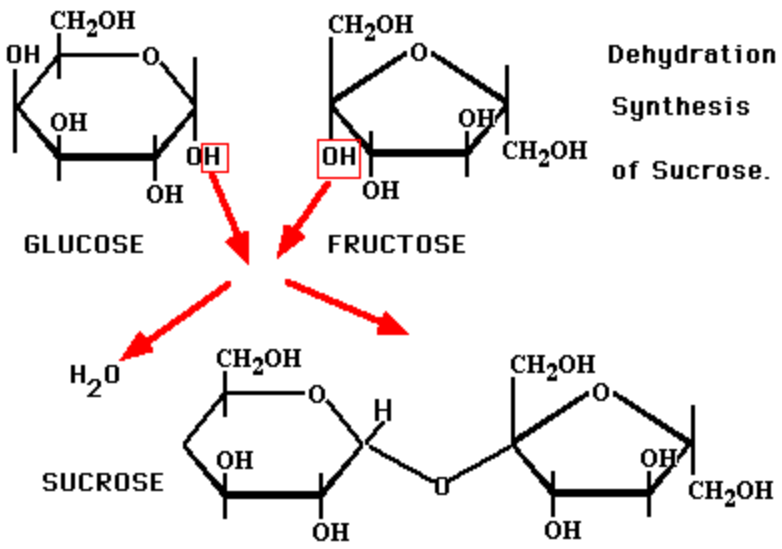




Carbohydrates

Structure

Monosaccharides



+ Galactose

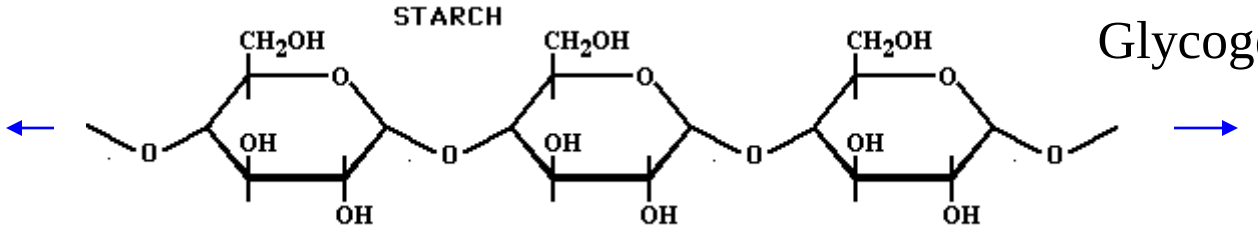
Disaccharides

+ Lactose
Maltose

Polysaccharides

+ Fibre

Glycogen



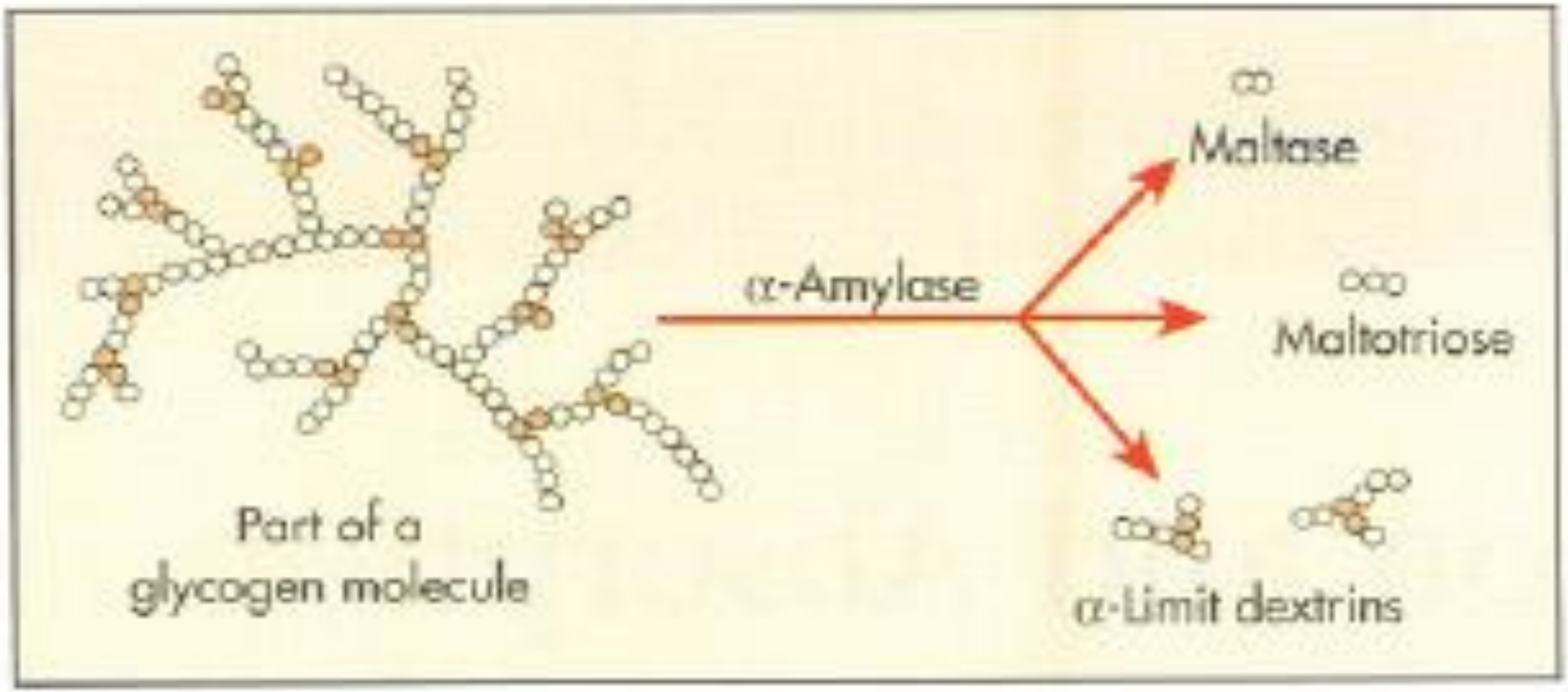
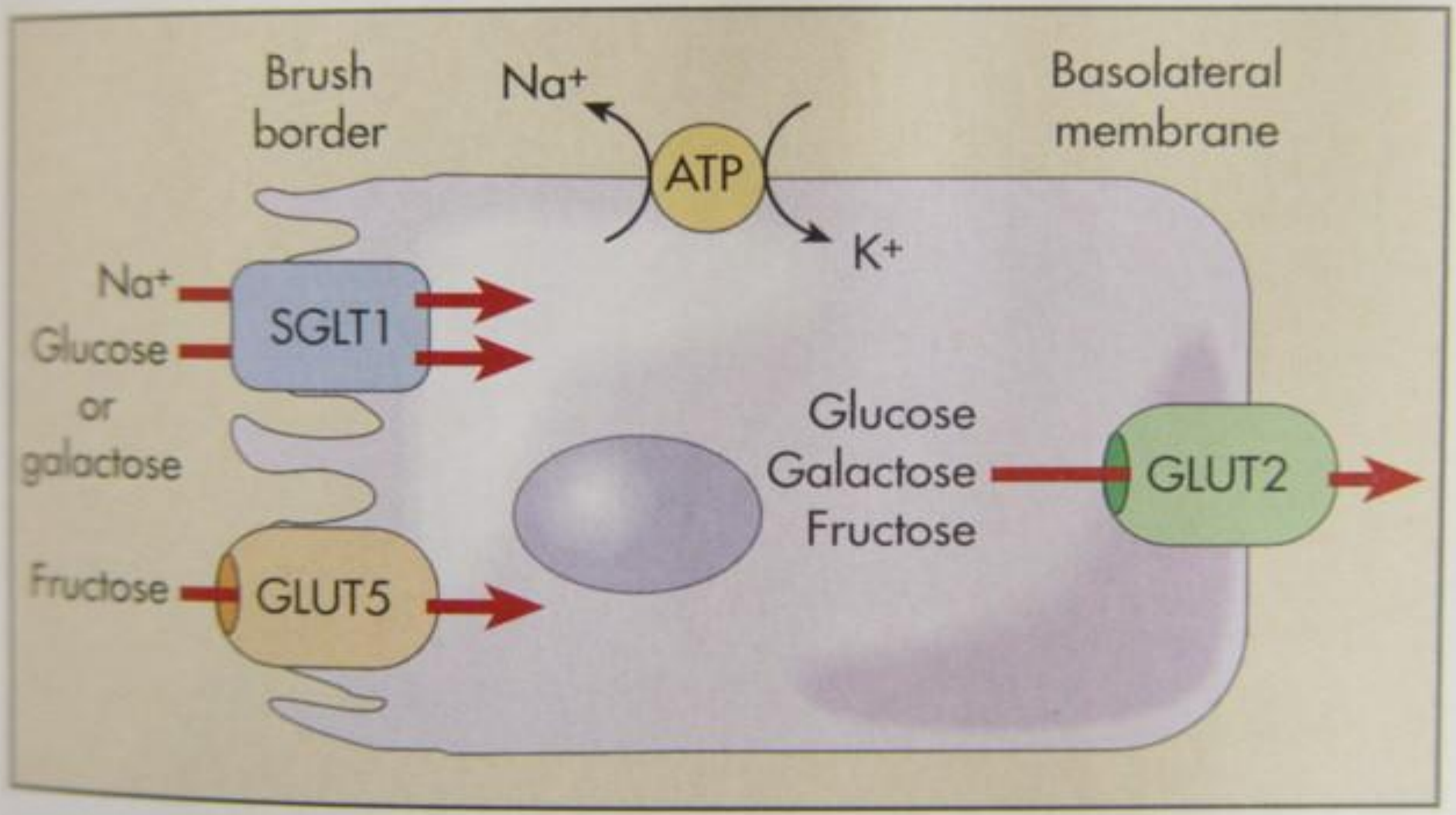


FIGURE 35–1. Structure of a branched starch molecule and the action of α-amylase. The circles represent glucose monomers. The colored circles show glucose units linked by α-1,6 linkages at the branch points. The α-1,6 links and terminal α-1,4 bonds cannot be cleaved by α-amylase.

Carbohydrate digestion & absorption

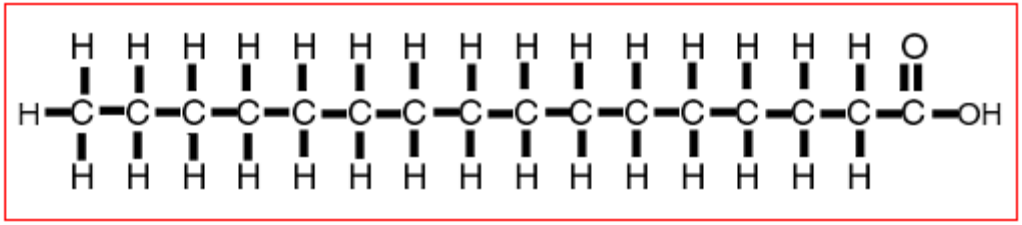
- Carbohydrate digestion involves the enzymatic degradation of di-, tri, and polysaccharides to monosaccharides (glucose, fructose, galactose).

- Digestion begins in the mouth with salivary amylase
- Polysaccharides are then further broken down by pancreatic amylase in the small intestine.
- Final degradation occurs on the surface (brushborder) of the absorptive cells in the jejunum. lactase, sucrase, and maltase.
- Monosaccharides absorbed by facilitated (membrane carrier) or active transport (membrane carrier, Na+, and ATP).
- Fructose = facilitated diffusion
- Glucose and galactose = active transport

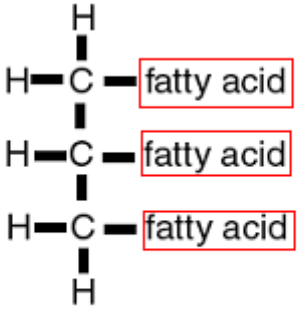

Brush
border
Na+
ATP
Basolateral
membrane
K+
Na+
Glucose
or
galactose
SGLT1
Glucose
Galactose
Fructose
GLUT2
Fructose
GLUT5

Fats

Fatty Acid



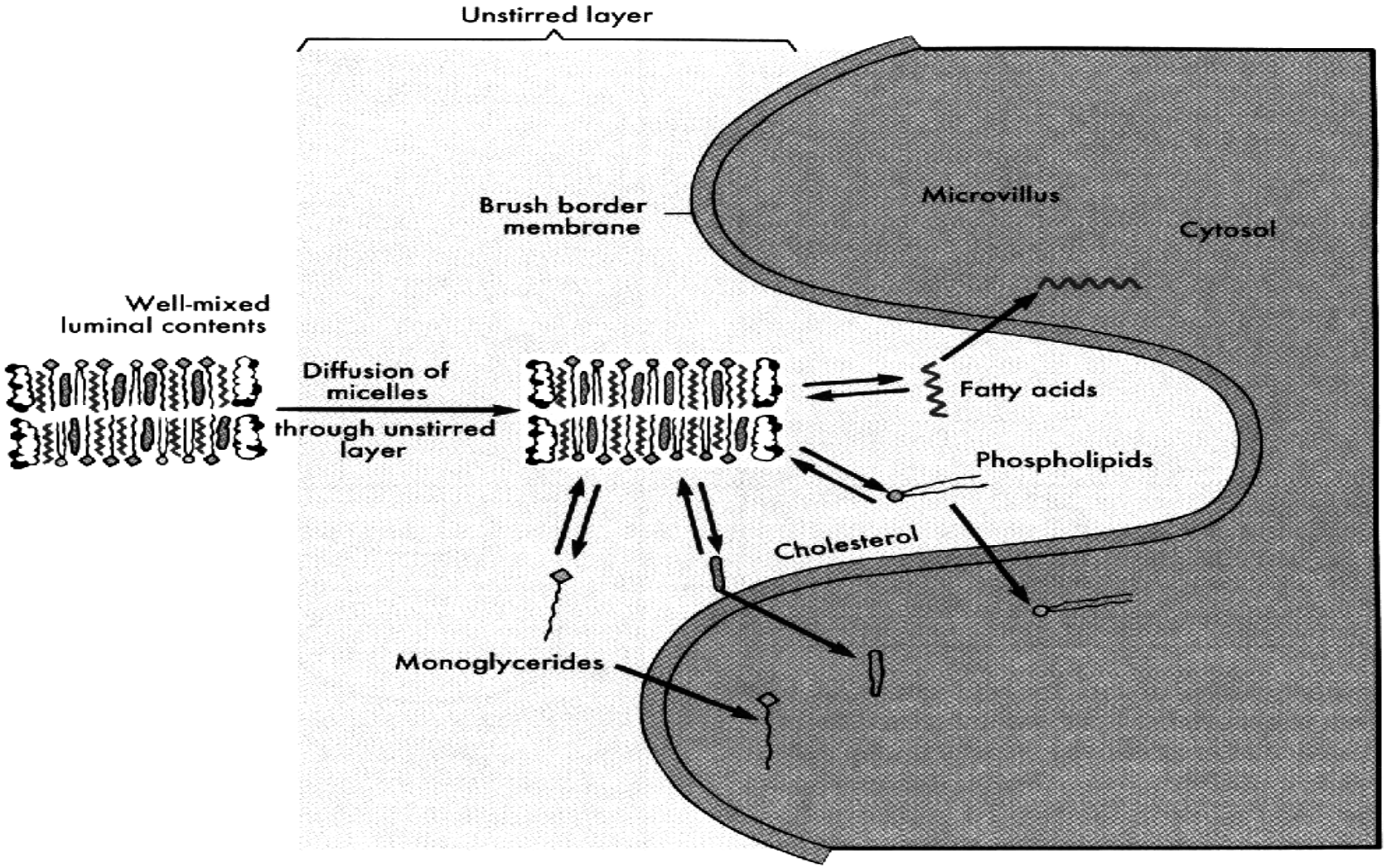
Fat (Triglyceride)



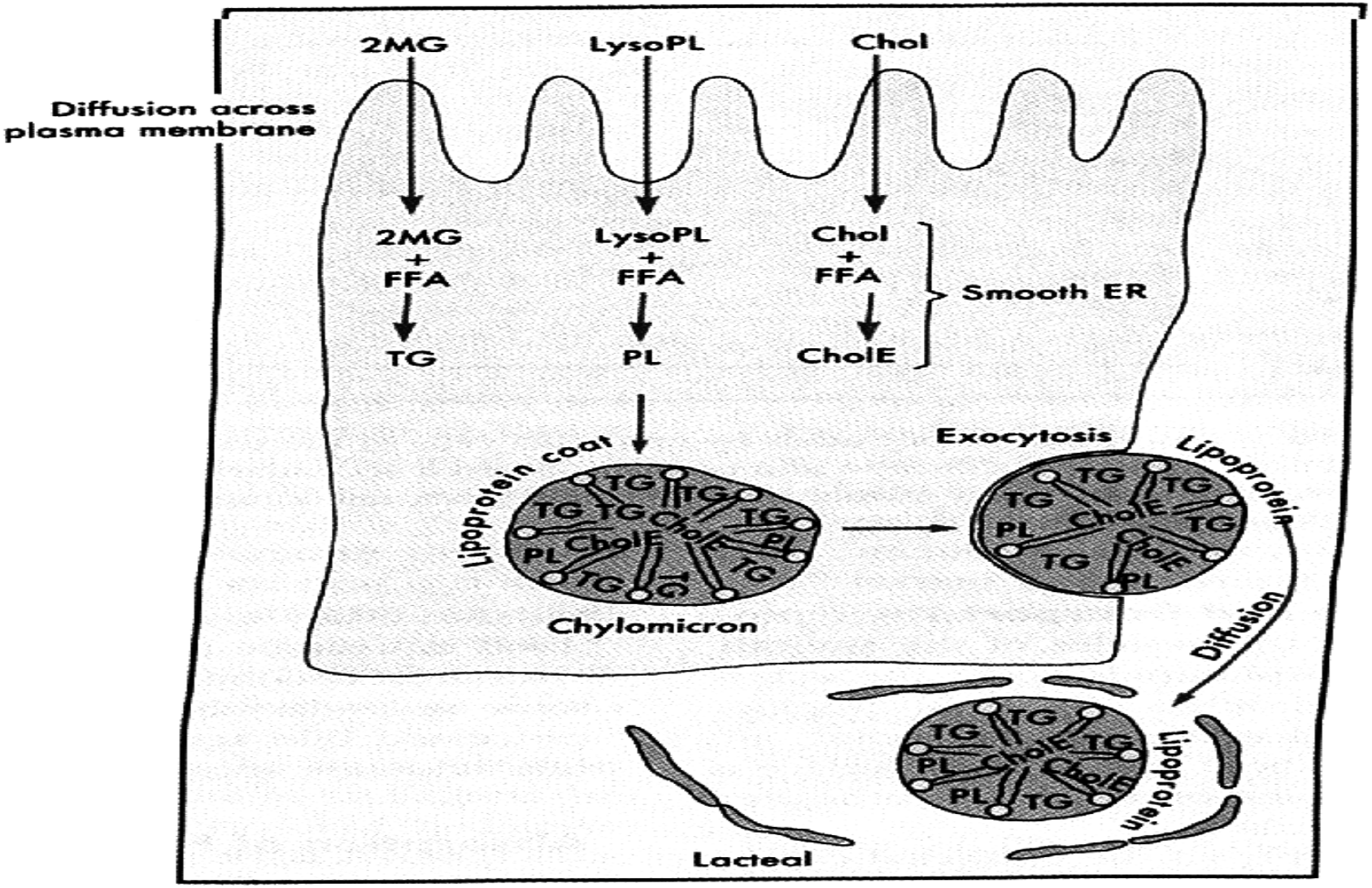
Lipid digestion and absorption

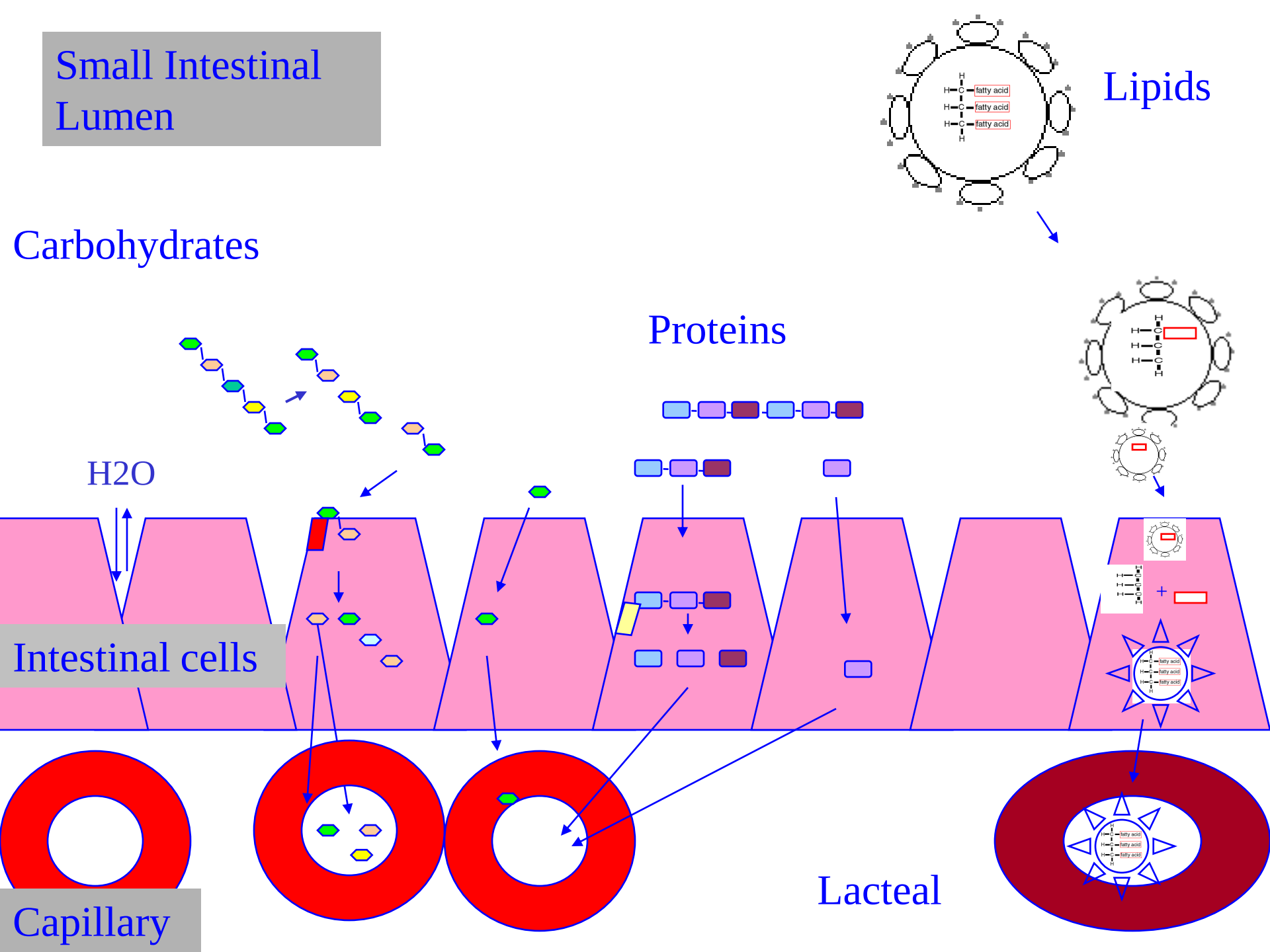
- Fats triacylglycerols (triglycerides) to monoacylglycerols and 2 fatty acids.
- Small amount of lipase in saliva begins digestion which continues in the stomach with (slow acting) gastric lipases.
- Pancreatic lipases and bile are mixed with hydrolyzed product in the duodenum. The bile emulsifies the fat into fat droplets (micelles) making it easier for colipase and pancreatic lipase to breakdown triglycerides
- Monoacylglycerol and fatty acids are packaged into mixed micelles (cholesterol, bile salts, and fat soluble vitamins) and diffuse across the cellular membrane (of the jejunum).
- Triglycerides are reformed (re-esterified) then combine with cholesterol and phospholipids to form chylomicrons for transportation

Lipid Absorption



Intracellular Metabolism of Absorbed Lipids




Small Intestinal Lumen
Lipids
Carbohydrates
Proteins
H2O
Intestinal cells
Capillary
Lacteal

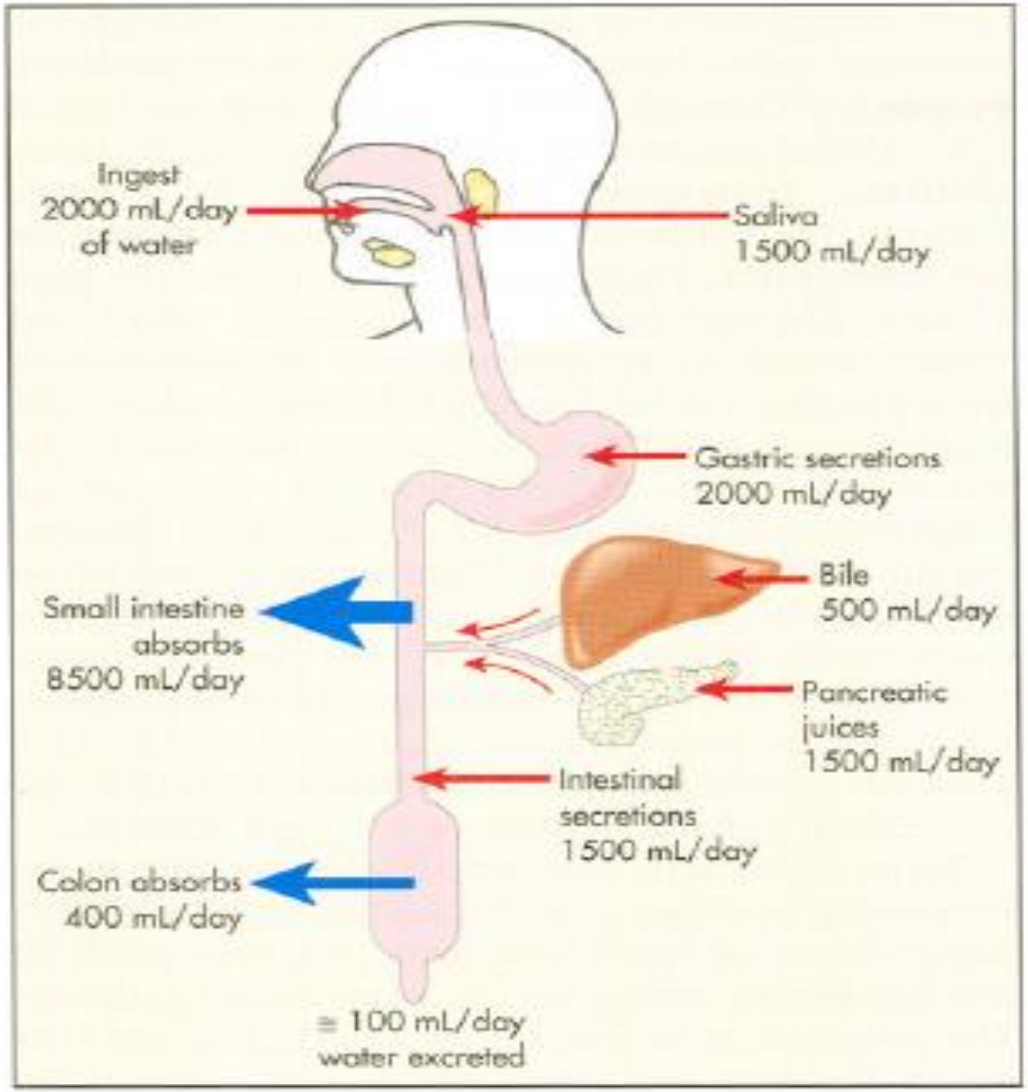
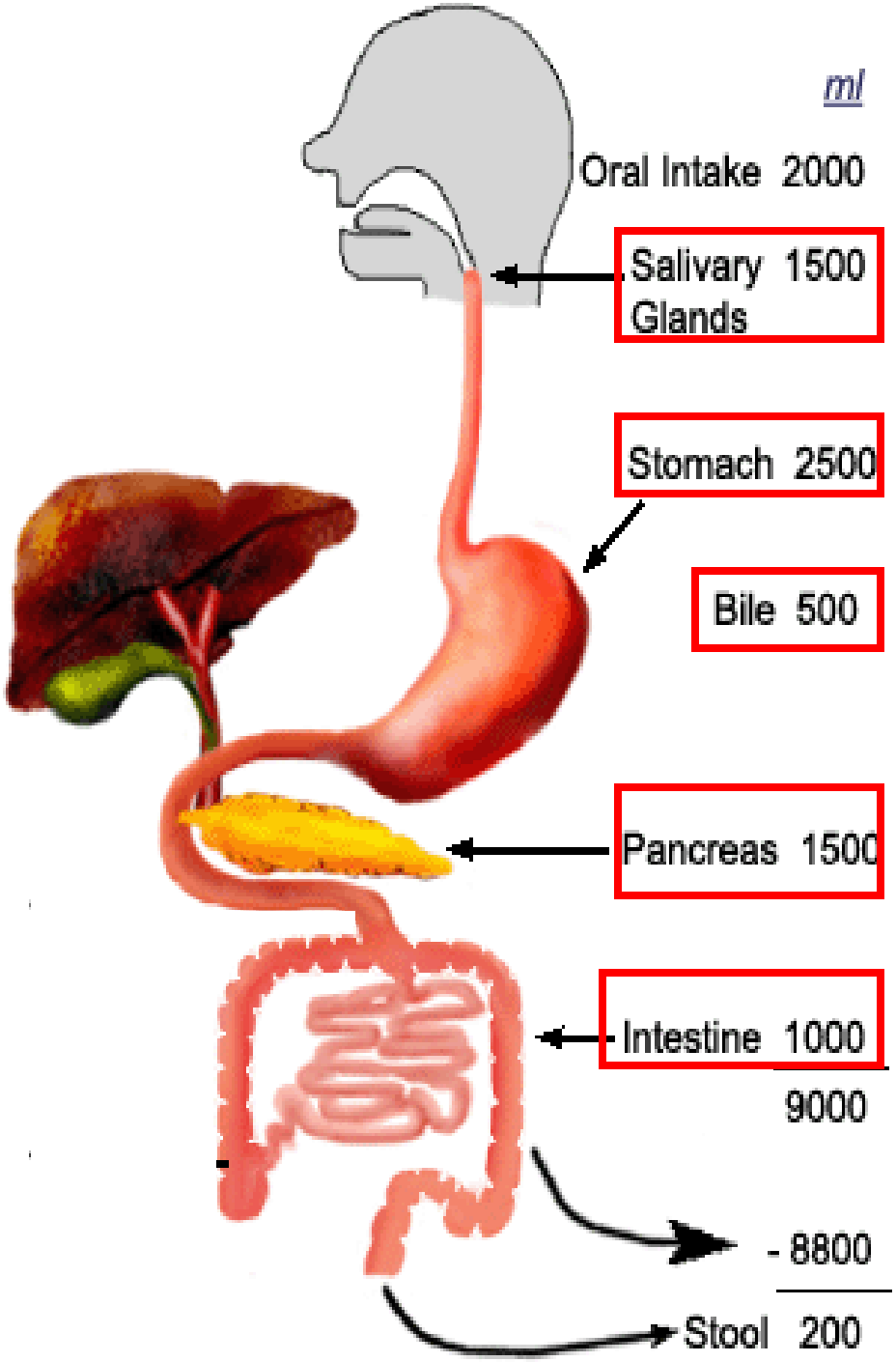
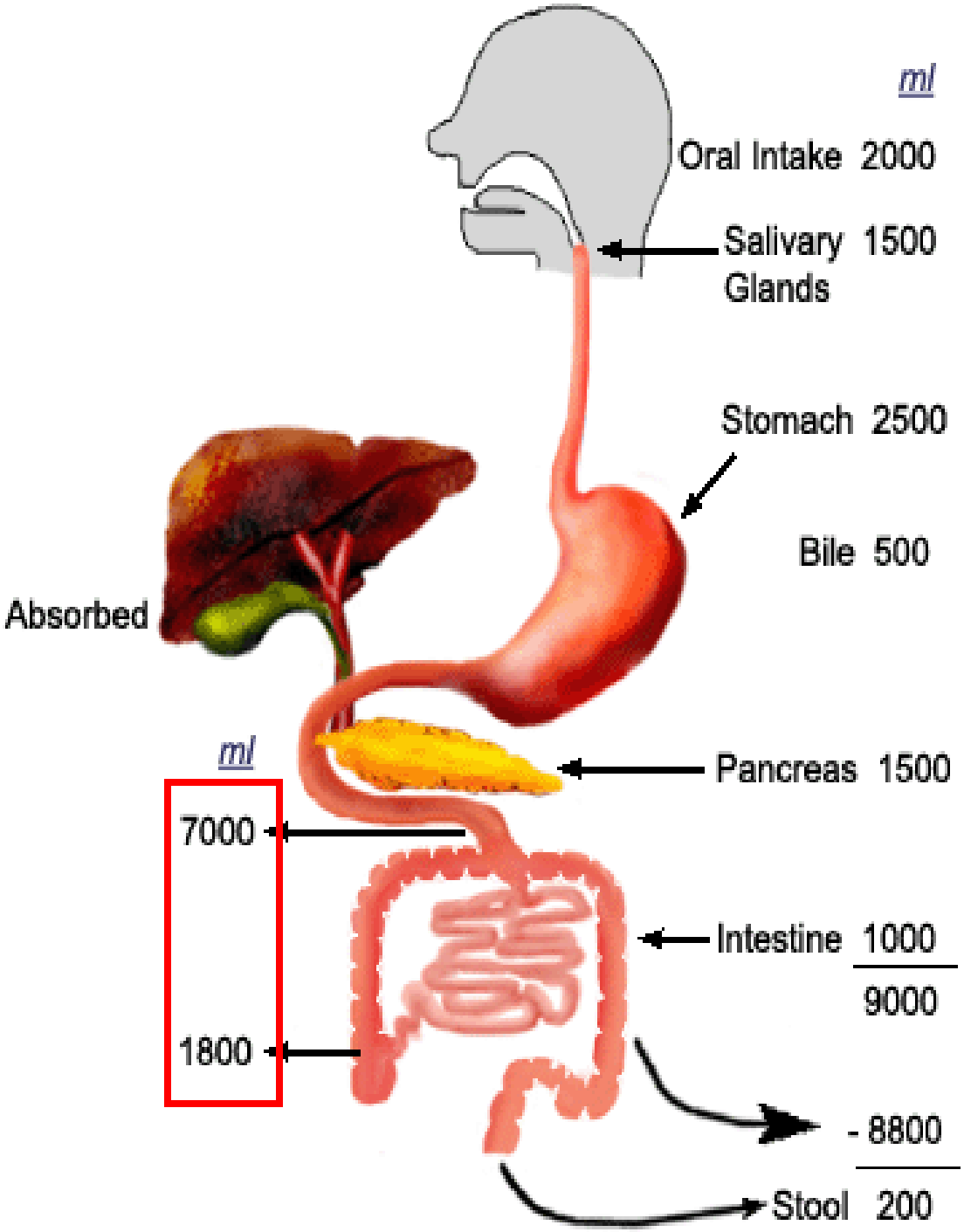
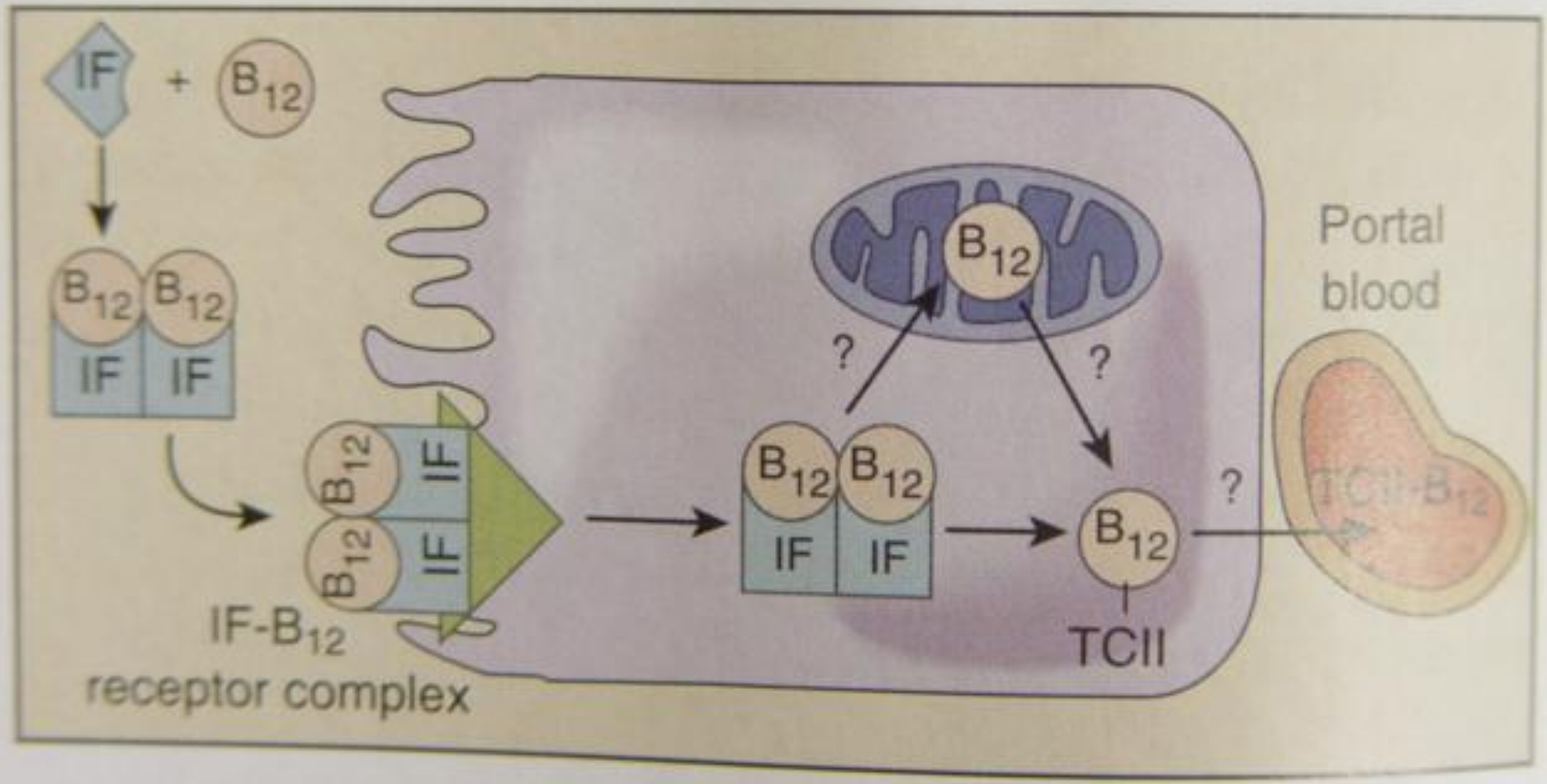


FIGURE 35–9. Overall fluid balance in the human gastrointestinal tract. Approximately 2 L of water is ingested each day, and 7 L of various secretions enter the gastrointestinal tract. Of this total of 9 L, about 8.5 L is absorbed in the small intestine. Approximately 500 mL is passed on to the colon, which normally absorbs 80% to 90% of the water presented to it.


ml
Oral Intake 2000
Salivary 1500
Glands
Stomach 2500
Bile 500
Pancreas 1500
Intestine 1000
9000
- 8800
Stool 200


ml
Oral Intake 2000
Salivary 1500
Glands
Stomach 2500
Bile 500
Absorbed
ml
Pancreas 1500
7000
Intestine 1000
9000
1800
- 8800
Stool 200

WHAT ?


IF
+
B_{12}
B_{12} B_{12}
IF IF
B_{12}
B_{12}
IF
IF
IF-B_{12}
receptor complex
B_{12}
?
?
B_{12} B_{12}
IF IF
B_{12}
TCII
?
Portal
blood
TCII-B_{12}

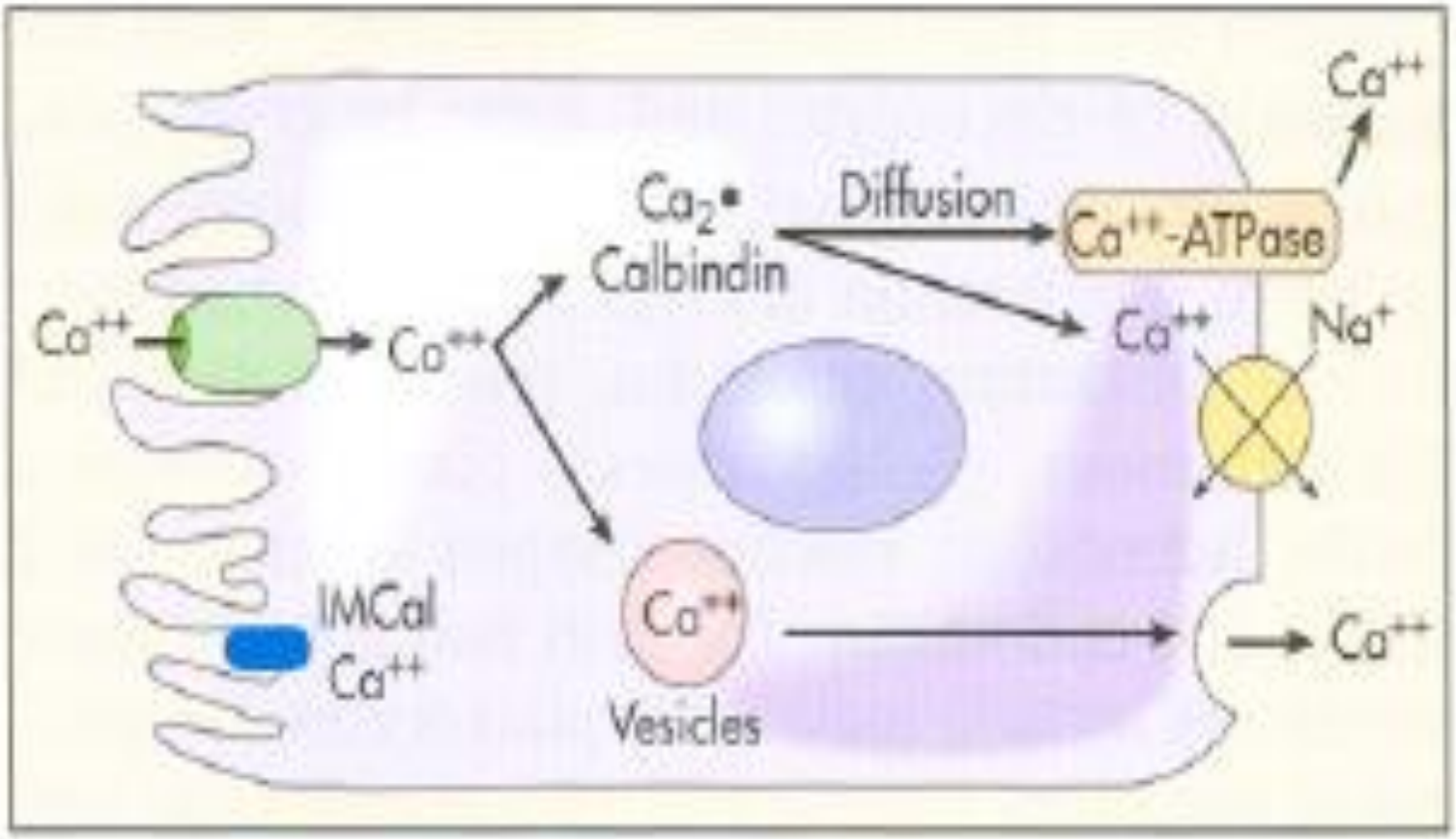


FIGURE 35–14. Cellular mechanisms involved in Ca^{++} absorption in the small intestine. IMCal, intestinal membrane calcium-binding protein.

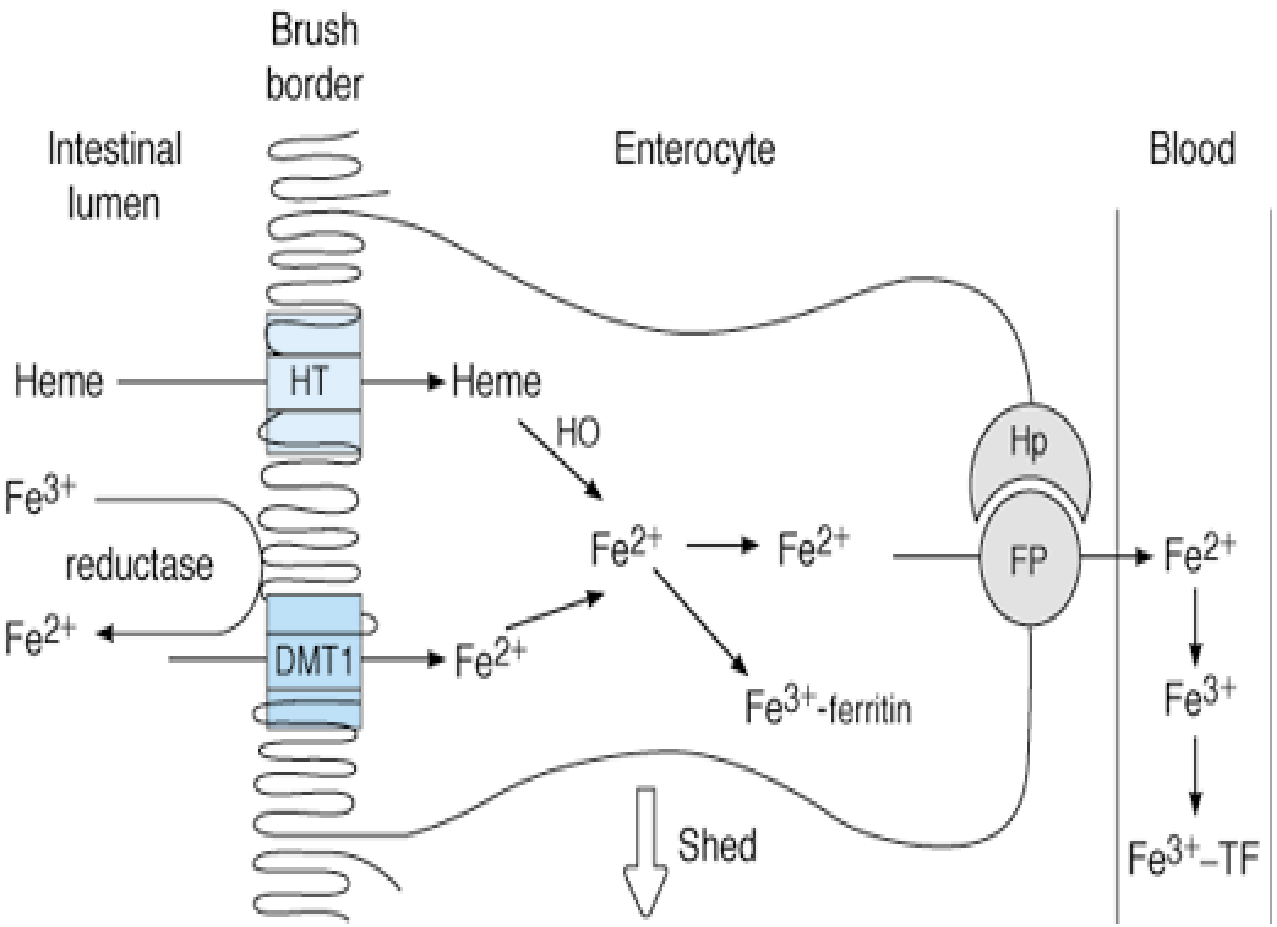


Figure 25-8. Absorption of iron. Fe^{3+} is converted to Fe^{2+} by ferric reductase, and Fe^{2+} is transported into the enterocyte by the apical membrane iron transporter DMT1. Heme is transported into the enterocyte by a separate heme transporter (HT), and heme oxidase (HO) releases Fe^{2+} from the heme. Some of the intracellular Fe^{2+} is converted to Fe^{3+} and bound to ferritin. The rest binds to the basolateral Fe^{2+} transporter ferroportin (FP) and is transported to the interstitial fluid. The transport is aided by hephaestin (Hp). In plasma, Fe^{2+} is converted to Fe^{3+} and bound to the iron transport protein transferrin (TF).